Décentralisation et environnement en Chine

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DECENTRALIZATION AND ENVIRONMENT IN CHINA

Thèse Nouveau Régime

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Pour l'obtention du titre de Docteur ès Sciences Économiques

Par

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Sous la direction de

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For the one who has gone to a better world…

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RESUME

Dans la littérature, les débats autour du fédéralisme environnemental sont persistants et non-concluants. La Chine a poursuivi la tendance globale de la décentralisation et adopté un *de facto* fédéralisme environnemental. Dans ce pays vaste et diversifié, connaissances et compétences locales sont nécessaires pour développer des solutions appropriées pour de nombreux problèmes environnementaux souvent avec une nature locale ou régionale. Cependant, malgré le *de facto* fédéralisme environnemental adopté, crises environnementales dramatiques et échecs de la politique sont répandus en Chine. En particulier, plus récemment, ce pays a vu apparaître de nombreux problèmes prédits par les opposants à la décentralisation. Il semble que, contrairement à la décentralisation fiscale qui a été un «coup de main» dans la mobilisation des ressources et la croissance économique au niveau sous-national, la décentralisation de l'application de la politique environnementale a plutôt été une «main saisissant» dans la gestion environnementale. Dans le but de fournir une compréhension meilleure et détaillée du *de facto* fédéralisme environnemental en Chine, cette thèse suit les différents critiques dans la littérature et teste empiriquement pour chacun d'eux dans le contexte spécifique chinois. En résumé, les résultats empiriques trouvés dans cette thèse soutiennent l'existence de problèmes liés à l'externalité environnementale, à l'interaction stratégique et aux incitations politiques qui conduisent au compromis de l'environnement. Par ailleurs, la décentralisation budgétaire en cours est susceptible de renforcer les interactions interprovinciales conduites par la concurrence pour capitaux; le déséquilibre fiscal est plus préjudiciable à l'environnement dans les provinces pauvres. Ces résultats appellent à un «nouveau fédéralisme environnemental» et une réforme des incitations, afin de transformer le *de facto* fédéralisme environnemental chinois d'une «main saisissant» à un «coup de main» pour une meilleure gouvernance environnementale.

ABSTRACT

In the literature, debate around environmental federalism is lasting and inconclusive. China has followed the global tendency of decentralization and has adopted a *de facto* environmental federalism. In this broad and diverse country, local knowledge and expertise is necessary to develop proper solutions for many environmental problems with local and regional nature. However, despite the adopted *de facto* environmental federalism, dramatic environmental crises and policy failures widespread in China. In particular, more recently, this country has seen arise many problems predicted by the opponents of decentralization. It appears that, contrary to the fiscal decentralization which has been a "helping hand" in resource mobilization and economic growth at the sub-national level, the decentralization of environmental policy implementation has rather been a "grabbing hand" in environmental management. With the purpose of providing a better and detailed understanding of the *de facto* environmental federalism in China, this thesis follows the different critics in the literature and test empirically for each of them in the Chinese-specific context. In summary, empirical results found in this thesis support the existence of problems related to environmental externality, strategic interaction and politically incentivized environment-sacrificing behaviors. Moreover, the current fiscal decentralization is likely to strengthen the capital-competition driven inter-provincial interaction; fiscal imbalance is more environmentally detrimental in poor provinces. These findings call for a "new environmental federalism" and a reform of incentives, in order to transform the Chinese *de facto* environmental federalism from a "grabbing hand" to a "helping hand" for better environmental governance.

General Introduction

Environment is a highlighted issue in nowadays China. Facing the strikingly high pollution level in this country which threatens its sustainable development, the Chinese government has engaged in a promise of environmental protection. More efficient environmental governance is essential for China. First, it is indispensable for the guarantee of the population's fundamental living and health right. Secondly, China's economic growth will not last without an ecologically sustainable society. Finally, environmental protection is also an inevitable responsibility of the Chinese government in the international community. Like many other policies in this country, environmental policy has been implemented in a decentralized way. While the creation of most environmental laws and rules are realized by the center, their enforcement is at the discretion of local environmental authorities. Given this context, some interesting questions attract one's attention: whether decentralization is an efficient model of political arrangement for environmental protection in China? In other words, what is the relationship between decentralization and the lasting environmental policy failures in China?

Decentralization: a worldwide tendency

For more than two decades, decentralization has been promoted by major international institutions in the worldwide and has become a tendency in many developing countries including China (World Bank, 2000). Defined as transferring authority and resources from central to lower tiers of government, decentralization is advocated by many scholars. According to the proponents of decentralization, local governments have greater proximity to the constituencies thus an information advantage over a central government; as a result, decentralization allows the former to better reveal and satisfy heterogeneous preferences of tax payers and improve local public good provision. However, in spite of the worldwide tendency, there are lasting and inconclusive debates over the effects of decentralization on social welfare. Quite different points of view exist in theoretical as well as empirical literature framework. Some scholars consider that more decentralization improves resource allocation, while others consider in the opposite way.

a. Proponent opinions

In the literature, studies defending decentralization are abundant. Classical channels through which decentralization improves local public good provision rely on assumptions that taxpayers of each jurisdiction express their preferences in their votes and that local government responds to these revealed preferences. Based on hypothesis of full mobility of consumer-voters, perfect information and absence of externality, Tiebout (1956) argued that inter-jurisdictional competition would arise in a decentralized circumstance and would beneficiate the allocation of local public services, because consumer-voters could choose their favorite municipality by "voting with their feet". The advantage that local governments can provide differential public goods in response to heterogeneous preferences is also defended by Oates (1972). Another classical advantage of decentralization is that, due to greater proximity to the constituencies, local governments have an information advantage in preference revealing compared to their central counterpart (Hayek, 1945).

Recently, more explicit political economy analysis of the decentralization attaches importance to political competition and incentives in the public sector (Besley and Coate, 2003; Seabright, 1996). This second generation of literature often argues that decentralization can help to increase local government's accountability to local citizenry through local elections. In a country like China, local accountability can also be improved by what is known as "yardstick competition", through which higher-level government evaluates jurisdictions in accordance with a set of standardized performance criteria (Liu *et al.*, 2006). In addition, it is often argued that decentralization can reduce corruption because politicians are held directly accountable for their actions under decentralization (Fisman and Gatti, 2002a; Fisman and Gatti, 2002b; Tabellini, 2000). Finally, in terms of scale and scope economy, government size is considered to play a significant role in its efficiency performance; losses with an excessively large government can also be an argument against centralization (Balaguer-Coll *et al.*, 2010).

b. Opponent opinions

Arguments in favor of centralization have frequently been based on the Pigouvian assumption that a government's objective is to maximize social welfare (Liu *et al.*, 2006). On one hand, tax competition may create inter-jurisdictional externalities and reduce local government efficiency (Gordon, 1983); When there is competition for capital, it might lead to a "race-to-the bottom" in local tax rates and a distortion in public goods provision (Oates, 1972; Oates and Schwab, 1988). On the other hand, insufficient provision of public goods would occur particularly in case of positive spillovers, where a jurisdiction can exploit the externality by "free riding" his neighbors' provision effort (Oates, 2005). Two compelling examples of "free riding" are trans-boundary pollution control and fight against terrorism. According to Oates (1972), there is a trade-off between decentralization and centralization whose resolution depends on the extent of heterogeneity in tastes and the degree of spillovers. Opposite to the proponent opinions in the second generation of literature, some scholars argue that decentralization would generate more corruption (Prud'homme, 1995; Treisman, 2002), because local politicians are more susceptible and accessible to local interest groups; another argument is that a centralized structure might exploit scale and scope economy of public production, and as a result provide public goods more efficiently (Prud'homme, 1995).

Environmental federalism

Primarily focusing on the vertical division of environmental management responsibilities among different levels of government (Oates and Portney, 2003), environmental federalism researchers pay great attention to the efficiency of environmental policy decentralization. Following the first generation of decentralization literature, of particular concern in environmental federalism is the ability of a nationally centralized regulatory structure to address environmental problems that are largely local and regional in nature. Just like policies in other social domain, "one-size-fits-all" can very easily become "one-size-fits-nobody". It is often argued that for environmental problems that are highly localized, it makes more sense to set standards for environmental quality that reflect local conditions rather than uniform national standards (Schwab, 2005). Driven by these preoccupations, a call for a return of substantial policymaking authority to state and local governments has been seen in the U.S. in the 1990s: according to the devolutionists, federal rules and procedures are often too complex, conflicting, inflexible and inadaptable to local context (Adler, 1998).

However, in the environmental federalism literature, no consensus has been achieved on the efficiency of decentralization in providing environmental services. In effect, on the theoretical plan as well as on the empirical plan, evidences are quite mixed.

On the theoretical plan, three sets of arguments have been made in favor of a strong role of the central government in the U.S. context (Stavins, 1998): The first argument states that many environmental problems cannot be efficiently regulated by individual jurisdictions because of their cross-boundary externalities. This argument is solid for example in the cases of the acid rain and the trans-boundary river pollutions. Secondly, in the absence of centralized controls, states would compete each other by lowering their environmental standards in order to attract mobile capital, and thus result in a so-called "race to the bottom" in environmental stringency (Kunce and Shogren, 2002, 2005; Levinson, 1997; Markusen *et al.*, 1995; McAusland, 2003); Finally, the "public choice" related rationales argue that in the U.S., local political processes systematically undervalue the benefits of environmental protection and/or overvalue the costs, compared with Federal political processes (Revesz, 1997). It is also presumed that environmental advocacy groups are more effective at the national level (Stewart, 1977).

Meanwhile, theoretical arguments in favor of decentralization are also abundant. First of all, although cross-boundary externalities are a solid drawback of decentralization, some argue that it does not necessarily call for a centralized regulatory bureaucracy because other means e.g. Coasian negotiations among jurisdictions, regional authorities, and common law nuisance actions can deal with at least some spillover problems (Adler, 1998); others model with inter-jurisdictional spillovers among heterogeneous jurisdictions suggest that decentralization leads to globally efficient resource allocation, even in the complete absence of interventions by higher-level governments or Coasian bargaining (Ogawa and Wildasin, 2009). Then, in terms of capital competition, many studies suggest that under certain conditions, decentralization may alternatively lead to no difference in policy outcomes (e.g., Oates and Schwab, 1988) or efficient allocation of polluting firms (Wellisch, 1995). Some studies even suggest that under other conditions, strategic behavior by states would lead to standards that are excessively (inefficiently) strong (Revesz, 1997). Finally, it is argued that positive political economy provides no support for the assertion that environmental interests will be under-represented at the state or local level (Stavins, 1998).

Empirical studies also find mixed results on the impact of environmental policy decentralization. On one hand, numerous studies do find evidence on inter-jurisdictional environmental spillovers (e.g., Gray and Shadbegian, 2004; Helland and Whitford, 2003; Kahn, 2004). More importantly, Sigman (2005) examines water quality in rivers around the U.S. and suggests that under the Clean Water Act, U.S. states do free ride more when they have more autonomy in water pollution regulatory enforcement; Sigman (2002) shows that greater decentralization enhances stronger regional pollutant, which might result from inter-jurisdictional free riding. On the other hand, there is a general consensus that decentralization does not necessarily lead to a "race to the bottom" as much as the theoretical literature suggests (Fredriksson and Millimet, 2002b; Konisky, 2007; Levinson, 2003; List and Gerking, 2000; Millimet, 2003). Finally, while List and Gerking (2000) and Millimet (2003) find that decentralization in the 1980s hasn't led to a degradation of air quality, Fredriksson *et al.* (2006) shows that decentralization does lead to weaker environmental policy in developing countries, particularly for air pollution.

Environmental policy failures in China

Since the beginning of the economic reforms, China has established its environmental institutions and a framework of environmental laws, in adopting a *de facto* environmental federalism. However, despite the existing of a comprehensive environmental policy framework, dramatic environmental degradation has accompanied the spectacular economic growth. Environmental policy failures are widespread in this country. The efficiency of the Chinese environmental governance should be called into question.

a. *Environmental crisis*

Pollution problems in China attract worldwide attention. With the rapid industrialization and urbanization process, pollution reaches a critical level and threatens the sustainable economic development and public health in this country. According to the World Bank (2007), health costs and total costs of air and water pollution in China amount respectively to about 4.3 percent and 5.8 percent of its GDP. Chinese official data (Ministry of Health, 2008) suggest that cancer has become the first cause of death in China. The annual cancer death number would be about 1.8 million in the country. Cancer is the cause of 25% of total death in urban area and 21% of total death in rural area. Although without official recognition, the media talks about some more than 100 cancer villages spread throughout the country.[1] Besides pollution crisis, China has always seen frequent natural disasters, among which a lot are partially due to human behavior-related ecological damages.[2]

- ***Water pollution***

The water pollution in China is strikingly severe. Groundwater is graded on a scale from "I" to "V" in China, "I" being pure and safe to drink, "IV" usable only for

[1] http://news.ifeng.com/mainland/detail_2011_11/15/10660031_0.shtml.
[2] For example, drought and flood in many ecologically vulnerable areas.

industry and farming, and "V" unusable for any purpose and unsafe to touch. In 2010, water in more than 75% of 26 major lakes in China is unsafe to drink; among which 14 are grade "V" and worse. The China Watch Institute reported in 2006 that seventy percent of the country's rivers were contaminated (Li, 2006). A 2009 Ministry of Environmental Protection (MEP) report suggests that previous pollution figures have been severely conservative, in that they did not account for non-point agricultural waste which was at least as important as industrial pollution (Golding, 2011). Xinhua Agency, the state news agency of China reports in 2007 that 90% of Chinese cities' underground water sources are contaminated.[3]

- ***Air pollution***

A great number of Chinese cities suffer from serious air pollution. Energy consumption (especially coal consumption), the rapid growth in use of motor vehicles and construction are three main sources of air pollutants such as particles, SO_2, NO_x, and CO in most Chinese cities (UN, 2009). According to the Word Bank (2007), the economic burden of premature mortality and morbidity associated with air pollution was 157.3 billion yuan in 2003, or 1.16 percent of GDP. According to the same report, only 1% of the China's 560 million city dwellers breathe air considered safe by European Union standards (annual average PM_{10} levels below 40 $\mu g/m^3$). Even if evaluated with China's own standard (annual average PM_{10} levels below 100 $\mu g/m^3$), still more than one quarter monitored cities fail to meet it in 2010.[4] The World Bank estimates that 16 of the 20 most polluted cities in the world are located in China (UN, 2009). Moreover, China overtook the United States in 2007 as the world's largest annual emitter of energy-related CO2, as shown by IEA (2010). In terms of policy failure, at the end of 2005, China has met none of its 7 critical 10th five year-plan targets for air pollution control.

[3] http://news.xinhuanet.com/world/2007-03/21/content_5874562.htm.
[4] Data published by the MEP in 2011, http://wfs.mep.gov.cn/dq/kqzl/201106/t20110603_211634.htm.

- ***Pollution accidents***

Pollution disasters has amplified since recent years: in November 2005, a major pollution accident of the Songhua River, owing to the explosion of a petrochemical plant, has forced the suspension of water supplies to the city of Harbin, home to 3.4 million people; In June 2007, a fetid bloom of blue-green algae in China's third-largest lake hit the city of Wuxi in east China. Water quality deteriorated severely and the water supply to a great number of households was contaminated; In July 2010, one gold mine of Zijin Mining, the biggest gold mining company in China, leaked 2.4 million gallons of acidic copper waste into the Ding River and a reservoir in Fujian. The pollution caused major contamination: 2000 tons of fish were killed or poisoned by the slush pond. In mid-August 2011, a chemical factory in Yunnan province had dumped 5,000 tons of toxic chromium tailings into a reservoir. The resulting water pollution killed fish and livestock and endangered the drinking water of tens of millions of people downstream.[5] Another highlighting issue is the heavy metal pollution accidents. 14 officially recognized heavy metal pollution accidents took place in 2010,[6] among which 9 were related to lead. In the eight first months of 2011, another 11 accidents broke out, 9 of which were due to lead.[7]

b. Problems related to the de facto environmental federalism

Pollution problems in China are not only remarkable for their severity but also for their complexity. In particular, it seems that China is seeing arise various problems predicted by the environmental federalism literature, i.e., trans-boundary pollution, destructive competition, and local interested environmental-sacrificing behaviors.

[5] http://www.chinadialogue.net/article/show/single/en/4493.

[6] MEP (2011), http://www.mep.gov.cn/zhxx/hjyw/201106/t20110604_211691.htm.

[7] http://news.xinhuanet.com/fortune/2011-10/25/c_111123430.htm. Lead is a toxic metal that can damage the brain and other parts of the body. Among other cases, in January, 2011, more than 100 children were found to have blood lead level exceeding the national standards in Huaining County, Anhui. Two months later, more than 170 villagers were found to be contaminated by the same heavy metal in Taizhou, Zhejiang.

- ***Trans-boundary pollution and inter-jurisdictional conflicts***

Trans-boundary pollution in China has attracted great attention since recent years. Very often, pollution crossing jurisdictional borders can induce fierce conflicts between involved regions, which are generally difficult to coordinate because of administrative discontinuity.

It is particularly the case for trans-boundary rivers, such as the famous Huai River which flows through 4 provinces (Henan, Shandong, Anhui and Jiangsu). Cross-province pollution has been frequently subjects of conflicts between upstream provinces and downstream provinces. For example, during several years, downstream cities (Bozhou, Suzhou, Huaibei and Fuyang) of Anhui province have been accusing upstream cities (Shangqiu and Yongcheng) of Henan province of dumping great volumes of wastewater in the Huai River, which caused enormous economic damage to the downstream fishery resource.[8] Similar cases are also relevant in the Tai Lake Basin (Jiangsu, Zhejiang and Shanghai). For example, conflicts between the downstream city of Jiaxing, Zhejiang province, and the upstream city of Suzhou, Jiangsu province, had been left unresolved for ten years and led to an extreme public event in November, 2001, when inhabitants of the former blocked the river by sinking boats (Peng, 2009).

- ***Competition for polluting industries***

Another recent and highlighting inter-jurisdictional environmental issue in China is the relocation of polluting industries from more developed regions to less developed ones. Generally, receptor provinces have less stringent environmental regulation. Putting priority to economic growth, these provinces use not only lax environmental regulation but also many tax exemptions and preferential land rents to attract

[8] http://218.23.173.119/XxgkNewsHtml/SA028/200811/SA028011102200811003.html.

investment. For example, according to some media reports,[9] the culprit of the blood lead accident in Huaining (Anhui) is a lead-acid battery producer who had relocated form Changxing (Zhejiang). Former capital of lead-acid battery industry in China, Changxing (Zhejiang) has severely regulated this sector since 2004 because of its colossal pollution and seen almost 70% of its production relocated by 2010 to other provinces, such as Anhui, Shandong, Henan, Jiangxi, etc. Another similar example is the competition among the Yangtze River Basin cities for petrochemical industries.[10] It is reported that many upstream provinces wait and aim for attracting chemical industries shut down in eastern provinces like Zhejiang, because of strengthening of environmental regulation enforcement. The consequence of these relocations is that polluting industries like lead-acid battery continue to pollute and cause important damages in other provinces.

Moreover, the relocation of polluting industries will probably be reinforced in the near future. In January, 2010, the first National Demonstration Zone for Industrial Relocation (NDZIR) was approved by the State Council to set up in Anhui province.[11] After that, numerous similar zones[12] have been created in other central and western provinces, with the purpose of receiving industries which are no longer competitive in eastern provinces. This national relocation strategy approved by the center[13] can be a significant environmental threat for receptor provinces which have a risk of becoming "pollution haven" for polluting industries discarded by more developed regions.

- ***Self-interested local governments***

As argued in the environmental federalism literature, one potential problem of decentralization is the "public choice" related rationales. Assumed to be

[9] http://news.163.com/11/0413/02/71G34N5700014AED.html.

[10] http://env.people.com.cn/GB/5264444.html. It is reported that more than 20 chemical industry parks are under construction along the Yangtze River in 2007.

[11] http://news.xinhuanet.com/fortune/2010-01/21/content_12851189.htm.

[12] In October, 2010, the 2nd NDZIR was approved to set up in the Eastern Guangxi, see http://xbkfs.ndrc.gov.cn/cyfz/t20111213_450392.htm; in January, 2011, the 3rd NDZIR was approved to set up in in Chongqing, see http://www.cq.xinhuanet.com/2011-01/31/content_21987054.htm. In October, 2011, the 4th NDZIR was approved to set up in the Southern Hunan, see http://news.xinhuanet.com/local/2011-10/28/c_122208214.htm.

[13] http://www.gov.cn/zwgk/2010-09/06/content_1696516.htm.

self-interested agents, local politicians may be incentivized to implement sub-optimal environmental policies. This problem is also highlighted in China. Until very recently, local governments have been primarily concerned with local economic interests and not accountable for their environmental performance. Consequently, environment has commonly seen being sacrificed for GDP scores, which have been equivalent to political achievements until very recently. Destructive competition for polluting industries is an example of self-interested behaviors. Another evidence of such behaviors is the widespread local protectionism, under which local governments interfere with environmental regulation in order to protect polluting but wealth creating industries.

Problematic and plan of the thesis

As shown in the above literature review, debate around environmental federalism is lasting and inconclusive. It seems that while decentralization has numerous merits in resource allocation and local public good provision, it may also lead to inefficient environmental policy making or enforcement.

Since the beginning of the economic reforms, China has adopted a *de facto* federalism to organize its fiscal system as well as its environmental policy implementation system. In this broad and diverse country, environmental concerns, preferences, and problems vary from place to place. The local and regional nature of many environmental problems means that local knowledge and expertise is necessary to develop proper solutions. However, in spite of its spectacular economic growth achievements during the last three decades, this country is experiencing dramatic environmental crises and seeing all kinds of problems related to environmental federalism. If there is little doubt that the fiscal decentralization has strongly facilitated the "pro-market" reforms and led to spectacular economic performances in China (Lin and Liu, 2000; Jin *et al.*, 2005), it seems that decentralization hasn't worked as efficiently in environmental protection as in economic growth promotion. As a result, China provides an ideal field to conduct empirical studies on the efficiency of environmental federalism. Meanwhile, given the current alarming environmental state, such studies are also indispensable and have important political implications for environmental governance improvement in this country.

In order to study the efficiency of the *de facto* environmental federalism in China, the following questions need to be investigated: What is the *de facto* federalism in China and for what reasons can it impact the environmental regulation enforcement? Has the *de facto* environmental federalism actually led to numerous problems predicted by the literature? And how does the *de facto* environmental federalism work under a set of Chinese-specific fiscal and political arrangements? In this thesis, these questions are studied in five chapters in an empirical way. The detailed plan of the thesis is as follows.

The *de facto* federalism (both fiscal and environmental) in the Chinese context is discussed in Chapter 1. Precisely, in presenting central-local fiscal relations and the institutional framework of environmental policy in China, I investigate the causality between the environmental policy failures and the *de facto* federalism in this country. I explain how the *de facto* environmental federalism and the one-sided fiscal decentralization have jointly provided Chinese sub-national governments incentives to exercise weak enforcement of environmental policies.

Chapter 2 is devoted to a cross-border pollution study, with the purpose of examining externality related problems argued by the opponents of environmental federalism. In studying the location choice of the most polluting firms of Hebei province over the period of 2002-2008, I try to examine, everything else being equal, whether polluting firms are significantly more attracted by border counties than interior ones in presence of intra or inter-provincial environmental regulation discontinuity. If the answer is yes, one can assume that free-riding behavior does exist, and that border counties have a risk of suffering disproportionally from environmental damages because of externality.

Another argument of decentralization opponents, i.e., strategic interaction across jurisdictions, is tested for in Chapter 3. Using provincial pollution levy data and SO2 emission data, and with different identification strategies, I test respectively for the capital-competition model and the pollution-spillover model. Precisely, using panel spatial econometric estimators, I try to find out whether Chinese provinces engage in strategic interaction in deciding their environmental stringency and SO2 emission level. I also test for the asymmetric interaction pattern predicted by the race to the bottom hypothesis, and the conditional effect of provincial fiscal imbalance on interaction behaviors.

Chapter 4 has the objective of testing for the third argument of decentralization opponents, i.e., the "public choice" related rationales. China has a centralized vertical bureaucratic system and a multidivisional-form (M-form) government structure. Until very recently, the political incentive within the bureaucratic system had been economic-performance targeted. It seems that this political incentive has had perverse environmental consequences in that it has incentivized sub-national officials to pursue economic growth at the cost of environment. In a political economy point of view, I consider a Chinese political market and examine the effect of political incentive by studying how political competitiveness and term limit affect provincial leaders' environmental performances. Particular attention is paid to institutional changes since 2006.

In Chapter 5, I focus on the environmental effect of the one-sided fiscal decentralization in China. Endowed with extremely mismatched revenue and expenditure assignments, Chinese provinces, especially the poorer ones, may have strong economic incentives to compromise environmental protection efforts. In this chapter, in a Stochastic Frontier Analysis (SFA) approach, I estimate the environmental efficiency (*EE*) scores of Chinese provinces' gross production as well as score determinants. Particular interest is given to the effect of fiscal imbalance on *EE*. I also examine whether the effect of fiscal imbalance is differential according to the provincial affluence, i.e., per capita income level.

In summary, this thesis is composed of a series of empirical studies in order to provide a better understanding of the *de facto* environmental federalism in China. It investigates each aspect of potential drawbacks of this institutional arrangement in the Chinese-specific context. It tries to identify the possible relations between the *de facto* environmental federalism and the widespread environmental policy failures in this country. Meanwhile, special attention is paid to another side of the *de facto* federalism, i.e., the central-local fiscal relations, which are high likely to work side by side with the *de facto* environmental federalism and interfere with sub-national environmental protection efforts. Interesting political implications can be drawn from the empirical evidences found in the thesis. These results will contribute to the search of a more efficient and well-organized environmental governance in nowadays China. In addition, from an international point of view, besides the constitutional federalism in the U.S. and the subsidiarity system in the E.U., China represents an alternative model of allocating environmental governance authority within a multilayer government (Lan *et al.*, 2011). Thus, a careful and detailed study of this special model also contributes to the global environmental governance literature.

Chapter 1 *De facto* federalism in China: relations with environmental policy failures

1.1 Introduction

China is a country with great geographical and administrative complexity. The administrative divisions of China consist of five levels of sub-national government, i.e., provinces, prefectures, counties, townships, and villages. As a entity, China administers 34 province-level regions, 333 prefecture-level regions, 2856 county-level regions, 40906 township-level regions and even more village-level regions (NBSC, 2011). While constitutionally organized as a unitary sovereign, government authority in China is actually a complex system of informal and formal divisions of authority between national and various levels of local political actors. Zheng (2007) argues that China's central-local relations are characterized by *de facto* or behavioral federalism. Although the federalism is not institutionalized, there is a long tradition of local authority in practice in China. A great number of studies investigated central-local relations in post-Mao era (Chung, 2000; Huang, 1996; Li, 2010; Landry, 2008; Zheng, 2007). These studies widely accept that the decentralization initiated by the 1978 reformists has endowed Chinese local governments with relevant authority in local economic development policymaking and resource allocation. Governments at various levels are considered to have maintained a firm hand in many economic matters, e.g. setting industrial policies, controlling (directly or indirectly) a large set of capital decisions, and participating directly in the management of major firms (Lan *et al.*, 2011). On one hand, local governments, incentivized by economic and political interests, have become major actors in promoting China's economic development. On the other hand, rapid local economic growth has in turn empowered these governments.

There is little doubt that this *de facto* federalism has promoted economic development in China for three decades. However, it is also argued that the decentralization has generated considerable problems, e.g., central-local interest conflicts, uncoordinated policies, and in some cases, growing localism. In effect, whatever the benefits of autonomy for sub-national governments may be, devolution of power from the center will tend to create or exacerbate problems where local officials face skewed incentives (Lan *et al.*, 2011). Numerous environmental policy failures in China provide such a case in point.

China's environmental policy framework has been elaborated at the beginning of the reform era and seen a rapid expansion in the late 1990s and the beginning of the new century (OECD, 2006). However, in spite of a quite comprehensive regulatory and institutional framework for environmental management, the law enforcement and policy implementation are still far from being adequate and effective. Following the national decentralization trend, *de facto* environmental federalism has been adopted to assign environmental protection responsibilities among central and local governments. Meanwhile, since the 1978 reforms and until very recently, national development priority has been given to economic growth over environmental protection. Given the structural conflicts between economic growth and environmental protection, the skewed incentive under decentralization is likely to be primarily responsible for the ineffective enforcement of environmental policy at sub-national level in China.

In this chapter, from a political economy point of view, I try to identify the relations between the *de facto* federalism and the ineffective enforcement of environmental policy in China. I show that the one-sided fiscal decentralization and the *de facto* environmental federalism have jointly provided Chinese sub-national governments with strong economic incentives as well as effective autonomy to exercise a weak enforcement of environmental policies. The rest of the chapter is organized as follows: in section 2, I present the current central-local fiscal relations in China and discuss why this one-sided decentralized system gives local governments economic incentives to compromise environment; in section 3, I present different elements of the environmental policy framework in China and discuss why the *de facto* environmental federalism contributes to weak enforcement. Concluding remarks are formulated in section 4.

1.2 One-sided fiscal decentralization and environmental policy failures

The *de facto* federalism in China is first of all illustrated by the organization of its fiscal system. Central-local fiscal relations in China have undergone substantial changes during the last thirty years. Before the beginning of the reform era, the fiscal system was fundamentally centralized, as a result of the strict central planning. In those days, as stated by Oksenberg and Tong (1991), all taxes and profits of state-owned enterprises accrued to the central government; local governments were in charge of collecting all taxes and acted simply as agents of the center; moreover, the central government set spending priorities for local governments and transferred to the latter necessary funds to meet their spending needs. Spending autonomy of local governments was thus extremely restricted.

Since the beginning of the 1980s, the old system had been proven inadaptable to the pace of the market-oriented reforms. In order to give local governments incentives to improve their tax collection, a fiscal contracting system was introduced in the 1980s. Under this system, local governments handed a fixed quota of tax revenues over to higher levels, and gained control of much of above-quota revenues (Jin *et al.*, 2005). In the same period, the central government devolved responsibilities for financing many public goods to local governments (Whiting, 2007). It is largely accepted that this fiscal contracting system had successfully encouraged local governments to develop economy in their jurisdictions (Lin and Liu, 2000); However, because of the periodic renegotiation of the sharing quota, fiscal contracting also created a strong incentive for local governments to conceal information about local revenue from the center. In practice, local governments were incited to hide revenues by shifting them off-budget, in order to obtain higher marginal revenue retention rates (Ahmad *et al.*, 2002). These strategic behaviors had resulted in serious consequences: on one hand, the central share of budgetary revenues fell to 22% in 1993 (Wong, 2007); the central government lost control over a large share of fiscal revenue. On the other hand, because of the expansion of off-budgetary funds, budgetary revenues as a share of GDP fell to about 11% by the mid-1990s.

With the purpose of restoring budgetary revenue and revamping central-local fiscal relations, the central government introduced in 1994 the TSS reform whose main content can be summarized as follows: first of all, taxes were divided into central, local, and shared categories, with major revenues controlled primarily by the central government; then, although vaguely, expenditure responsibilities of the central government were defined; furthermore, the fiscal transfer system was redesigned. The central government would transfer a part of the central revenues to localities, in order to balance their budgetary; finally, tax collection authorities were also separated into the National Tax Service (NTS) and the Local Tax Service (LTS). The NTS collects both central and shared taxes, and the LTS collects local taxes (The State Council, 1993). The TSS reform is proven to have stopped the declining of budgetary revenues as a percentage of GDP, which increased from 10.8% in 1994 to 20.7% in 2010. Figure 1.1 presents the evolution of national budgetary revenues level and their share in GDP over the last three decades.

Figure 1.1: Overall national budgetary revenues (1978-2010)

Source: China Statistical Yearbook (various issues) and author’s calculation.

1.2.1 Overview of current central-local fiscal relations

In the 62-year evolution of central-local fiscal relations since the creation of the P.R.China, the latest milestone is the tax sharing system (TSS) reform of 1994. Although some small modifications were made in the last few years,[14] the main characteristics of the fiscal system have remained the same since 1994: first, revenue allocations have been recentralized; secondly, expenditure assignments have remained largely decentralized; thirdly, local governments depend strongly on transfers from upper-level governments. In summary, the nowadays Chinese fiscal system is characterized by so called "one-sided" decentralization, where important fiscal gaps and vertical imbalances dominate.

1.2.1.1 One-sided decentralization

The TSS reform has shaped nowadays central-local fiscal relations in China. China's current fiscal system is characterized by some kind of "one-sided" decentralization, where fiscal revenues are recentralized while public expenditure responsibilities are extremely decentralized.

1.2.1.1.1 Revenue assignments

Sub-national governments in China do not have any significant degree of tax autonomy; Taxation legislation as well as tax bases and rates are decided at central level.[15] In this context, the TSS reform has furthermore recognized the dominant role of the central government in the intergovernmental fiscal system by introducing a radical reform in revenue assignments. Due to the new assignments, the objective of raising the central share of revenues has been achieved: The reallocation of revenues

[14] For example, the enterprise and personal-income taxes are to be shared between the central and local governments from January 1, 2002 onwards (Tsui, 2005).

[15] Article 8, Section 1, Chapter 2 of Law on Legislation of the People's Republic of China (2000) provides that basic systems of finance, taxation shall only be governed by law. As a result, tax legislative power should only exercised by The NPC and its Standing Committee. http://www.lawinfochina.com/display.aspx?id=386&lib=law. Actually, most of existing taxation laws and regulations in China are formulated by the State Council, authorized by the NPC.

drove the center's share of budgetary funds from 22% in 1993 to more than 55.7% in 1994 and 51.1% in 2010. The evolution of central and local budgetary revenues during the last two decades is presented in Figure 1.2.

Figure 1.2: Central and local revenues (1978-2010)

Source: China Statistical Yearbook (various issues) and author's calculation.

Although the TSS reform provided explicit revenue assignments between the central and provincial governments, revenue assignments at the sub-national level were left to the discretion of provincial governments (World Bank, 2002). In general, fiscal revenue resources are largely controlled by the up two levels (provinces and prefecture-level municipalities); while the lower two levels (counties and townships) have only limited revenue resources. However, the situation varies from one province to another. It seems that revenues are more "centralized" in some provinces than others. For example, in 2007, Beijing, Shanghai, Chongqing and Tianjin (the four provincial level municipalities) have the highest provincial level revenue shares, with 56.8%, 50.9%, 45.6% and 45.3%, respectively, while Henan, Jiangsu, Fujian and Zhejiang have the lowest provincial level revenue shares, with 8.8%, 10.3%, 10.3% and 10.9%, respectively.[16]

[16] Calculated by the author based on 2007 data published in Statistical Material for Prefectures, Cities, and Counties Nationwide (MOF, 2010)

1.2.1.1.2 Expenditure assignments

Expenditure responsibilities were largely decentralized at the beginning of the economic reform era. This trend has not been changed and even accentuated by the TSS reform. In broad terms, the TTS reform discusses the division of expenditure assignments between the central and local governments in China: the central government has responsibilities in national defense, diplomacy, the control and management of national agencies, and the control of macro-economy, while local governments have responsibilities in providing social services and matters relating to local economic development (The State Council, 1993). As shown in Figure 1.3, while overall national budgetary expenditures have been multiplied, the central share has seen an important decrease: in 1980, the central government spent more than 50% of national expenditure, contrasted to only 17.8% in 2010. In other words, in 2010, sub-national governments realized more than 80% of total expenditure responsibilities, which is strikingly high, even when compared to some important federal countries in the world.[17]

Figure 1.3: Central and local expenditure (1978-2009)

Source: China Statistical Yearbook (various issues) and author's calculations.

[17] For example, in 2010, the equivalent share in the United States and in Germany, two representative federal nations, is 59.3% and 73.9%, respectively. See http://www.usgovernmentspending.com/total_spending_2010, http://www.economywatch.com/economic-statistics/country/Germany/, and http://www.bundesfinanzministerium.de/nn_103442/EN/Topics/Fiscal-policy/Articles/13012011-NKA.html?__nnn=true.

Meanwhile, the country lacks a formal assignment of expenditure responsibilities among its different levels of sub-national government. Similar to revenue assignments, the division of sub-national expenditures is left to the discretion of the provinces. From an overall point of view, expenditures at sub-national level are strongly decentralized. In 2007, 48.2% of total sub-national expenditures were spent by counties' and lower levels of government, while the provincial and the prefectural levels accounted for only 23% and 28.8%, respectively. Tibet, Beijing, Tianjin and Qinghai had the highest provincial shares in their total expenditures (58.2%, 47.8%, 46.8% and 44%, respectively), contrast to Guangdong, Zhejiang Shandong and Jiangsu, with the lowest shares (10.8%, 11.5% 12.6% and 13.9%, respectively). Provinces with the highest counties' and lower level share are Zhejiang (66.4%), Jiangxi (65.9%), Sichuan (65.7%) and Shandong (62.6%). On the contrary, Shanghai (2.7%), Beijing (3.4%), and Tianjin (4.4%) had the lowest counties' and lower level share.[18] Expenditures are also more centralized in some provinces than others.

Figure 1.4: Division between different levels of government by expenditure function (2007)

Source: China Statistical Yearbook (2008), MOF (2010a) and author's calculation

[18] Calculated by the author based on 2007 data published in Statistical Material for Prefectures, Cities, and Counties Nationwide (MOF, 2010)

Sub-national expenditure assignments also vary by function. Figure 1.4 shows the division between different levels of government by expenditure function category. It is notable that among different functions, environmental protection is one of the most decentralized. In 2007, more than 95% of total budgeted expenditures on environmental protection were spent by sub-national governments, of which more than a half was realized at sub-provincial level.

Figure 1.5: Importance of different levels of sub-national government in environmental protection expenditure

Source: China Statistical Yearbook (2008), MOF (2010a) and author's calculations

Concerning the assignments of environmental expenditures among different levels of sub-national government, provincial variation is also striking. Figure 1.5 shows the shares of various levels of sub-national government in environmental protection expenditures in 2007 by province. The importance of provincial level expenditures varies from 5.78% (Guangdong) to 93.55% (Tibet); the importance of prefectural level expenditures varies from 2.95% (Qinghai) to 49.58% (Shanghai); and the importance of county and lower level expenditures varies from 1.07% (Shanghai) to 72.41% (Sichuan). These huge provincial heterogeneities provide strong evidences of the discretion when provinces organize their environmental expenditures.

1.2.1.1.3 Transfers

One of the aims of the TSS reform was to introduce a rule-based and formula-driven intergovernmental transfer system, in order to counter equalize the regional distribution of revenues (World Bank, 2002). The current fiscal transfer system, after the simplification in 2009, consists of three categories of grants, i.e. tax rebate,[19] specific purpose transfers (earmarked grants),[20] and general purpose transfers (subsidy transfers).[21] In 2009, the central government transferred 2856.38 billion yuan to local governments through the fiscal transfer system (MOF, 2010b). The relative importance of these three grants is presented in Figure 1.6. In 2009, specific transfers have the most relevant share (43%) in total grants. General purpose transfers are also important with a share of 40%.

As a result of the recentralization of revenues and the decentralization of expenditures, sub-national governments are largely dependent on fiscal transfers to ensure their spending responsibilities, which are sometimes difficult to fulfill. In 2009, total transfer grants (including tax rebate) account for almost 80% of central government's fiscal revenues and as much as 47% of sub-national expenditures.

[19] Tax rebate are composed of three parts. First, the central government gives back to each province 30 percent of its increased revenue from the VAT and consumption tax each year over the 1993 base; secondly, the central government compensates each province for its loss in income tax revenue due to the 2002 income tax reform, compared to 2001 base, and finally, after the implementing of the price and tax reform of refined oil, provinces receive the compensation from the central government based on their revenue of "six fees" in 2007.

[20] These grants are allocated on an ad-hoc base in order to ensure that certain specific policies and development strategies are implemented efficiently at local level. They are also used to afford redress to local governments for central-local shared affairs or missions devolved by the central government. Earmarked grants were initiated in 1999 and reflect many different government policy initiatives, e.g. infrastructure projects, agriculture, health, wage subsidies, etc.

[21] These transfers are assumed to be formula-based, with function of offsetting the gap between revenue and expenditure at local level, and equalizing the capacity of providing public service across regions. The utilization of general purpose transfers is left to the discretion of the provinces. Since 2009, some transfers for education, social security and employment, public security and general public services, which were earmarked grants, have been reclassified in general purpose transfers.

Figure 1.7 shows the correlation between provincial dependence on central government's fiscal transfers and provincial economic development level in 2008. Obviously, the dependence degree is negatively correlated to per capita gross regional product (GRP), i.e., poorer provinces are more dependent on central government's fiscal transfers than more affluent ones. Among all provinces, the most dependent one is Tibet with 94% of its total expenditures covered by transfers, while the less dependent one is Beijing with transfers accounting for only 14% of its total expenditures.

Figure 1.6: Relative importance of the three grants (2009)

Source: MOF (2010b).

Figure 1.7: Dependence of provinces on central government's fiscal transfers in 2008

Source: Author's calculation based on China Statistical Yearbook (2009) and Finance Year Book of China (2009)

Transfers are of vital importance for sub-national governments in China. However, the current system of intergovernmental transfers has got a lot of criticism (Ahmad *et al.*, 2002; Tsui, 2005). It is often considered that in spite of the large volume of flows, this system has not been efficient in redistributing resources, especially at the beginning of the post-TSS era when tax rebate predominated in the total grants.[22] Tax rebate is considered to be not equalizing because it accrues to the benefit of the wealthier provinces and intends to safeguard their immediate interests by preventing severe decline in revenue after the TSS reform. Earmarked grants have the potential to be equalizing, but a potentially dis-equalizing element in earmarked grants is the requirement for matching funds from local governments in order to access many of these grants (Whiting, 2007). Moreover, these funds are subject to lack of transparency because they are often allocated on an ad-hoc base. Bargaining power of provinces is still essential for these funds' allocation (Bahl, 1999).

Figure 1.8: Dis-equalizing to equalizing transfers (1999, 2005, and 2009)

(a) 1999

(b) 2005

(c) 2009

Source: China Statistical Yearbook (2000; 2006; 2010) and Finance Year Book of China (MOF, 2000; 2006; 2010)

[22] In fact, the rebate accounted for about three-quarters of central transfers during the mid-1990s (World Bank, 2002).

Figure 1.8 (a, b and c) relates per capita transfers received by each province and provincial GRP per capita in 1999, 2005 and 2009, respectively. According to the figure, in 1999, transfers per capita are positively correlated to provincial GRP per capita, i.e., richer (poorer) provinces get more (less) transfers. The transfers were thus rather dis-equalizing than equalizing. Nevertheless, due to the decrease of the share of tax rebate and the increase of the share of general purpose transfers in total grants, transfers were less dis-equalizing in 2005. Figure 8(c) shows that transfers became equalizing in 2009, when per capita transfers and provincial GRP per capita were negatively correlated to each other.

1.1.1 Consequences of current one-sided fiscal decentralization on environmental protection

The one-sided fiscal decentralization after the TSS reform has created significant fiscal (revenues - expenditures) gaps at the sub-national level in China. Provincial fiscal gaps in 2010 are illustrated in Figure 1.9: It is notable that all Chinese provinces are exposed to fiscal (revenues - expenditures) gaps without any exception. The most important fiscal gap is found in Tibet, which accounts for 93.35% of its expenditures in 2010. The province the less exposed to fiscal gap is Shanghai, with 13% of its expenditures uncovered by its revenues in 2010. Consistent with the dependence on central transfers (illustrated in Figure 1.5), more affluent provinces have generally less important fiscal gaps.

Generally, sub-national governments in China depend to a large extent on intergovernmental transfers, which are not always transparent or adequate.[23] It is argued that in many poor localities, the one-sided decentralization has often led to the under-provision of basic public services (Martinez-Vazquez *et al.*, 2009). Several factors can explain why environmental protection services would be underprovided under such a system.

[23] This situation has also driven sub-national governments to be reliant on informal fiscal tools, such as extra-budgetary sources of funding, indirect borrowing at the sub-national levels and land sale.

Figure 1.9: Provincial fiscal gaps in 2010

Source: Data published in China Statistical Yearbook (2010)

First, local governments (and their EPBs) may be obliged to maintain weak environmental enforcement due to fiscal incapacity. Sub-national governments have excessively heavy expenditure responsibilities which are mismatched with their revenue assignments (World Bank, 2002). It is argued that, in many poor regions, fiscal resources are so insufficient that public finance is reduced to some kind of "dining finance" (*chi fan cai zheng*), which means the payment of civil servants' wage (Jing and Liu, 2009). Given the severe budgetary pressures, certain local governments, especially those of poor localities, can fail to provide sufficient environmental services or inspection due to lack of funding, quality personnel and (or) equipment.

Secondly, weak environmental enforcement is also likely to arise due to unwillingness. Qian and Roland (1998) argue that in the inter-jurisdiction competition for foreign capital and grants from the central government, local governments will have incentives for too much infrastructure investment and too few local public goods for a given budget. As a result, when taking budget priority decision, local governments may have reluctance to spend money in "unproductive" areas such as environmental protection. Moreover, it seems that this unwillingness for more stringent environmental enforcement can be reinforced by the severe local budgetary pressures. On one hand, mismatched revenues and expenditure responsibilities force local governments to trade off between different functions (e.g., infrastructure and environmental protection.) On the other hand, in order to fulfill their responsibilities, local governments struggle to enlarge revenue resources. In particular, they may be incentivized to set sub-optimal environmental stringency to attract polluting capital or to engage in other short-sighted activities that may compromise environmental protection.[24]

Finally, mismatched expenditures and revenues can also affect environmental through corruption. On one hand, as argued by Fisman and Gatti (2002b), vertical fiscal transfers may allow local officials to ignore the financial consequences of mismanagement. Moreover, transfers may attenuate the direct accountability of a politician in his locality. The authors find that larger federal transfers are associated with higher rates of conviction for abuse of public office in the U.S.; On the other hand, corruption is found in many studies to be an important factor of bad environmental governance and environmental deterioration (Lopez and Mitra, 2000; Welsch, 2004). As a result, one may expect that the Chinese one-sided fiscal decentralization may contribute to ineffective enforcement of environmental regulations due to enlarged corruption.

In summary, it seems that the current one-sided fiscal decentralization imposes important constraint on sub-national governments' enforcement capacity of

[24] A concrete case of the short-sighted activities is the sale of farmland to real estate developers by Chinese local governments. It is estimated that about 40 million farmers have been stripped of their land by local governments. http://www.china.org.cn/learning_english/2011-11/08/content_23852110.htm.

environmental regulation. More importantly, the one-sided fiscal decentralization generates particular economic incentives for weak enforcement of environmental policies in China. Under the strong fiscal pressure, sub-national governments are incentivized in several ways to neglect environmental protection or to save their enforcement efforts.

In the following, I'll turn to another side of federalism – the *de facto* environmental federalism, which may affect environmental policy outcome more directly.

1.3 *De facto* environmental federalism and environmental policy failures

In the sub-section, firstly, I present how environmental policy is designed and implemented in the framework of *de facto* federalism. Then, I explain why this *de facto* environmental federalism can be related to policy failures

1.3.1 Environmental policy framework in China

1.3.1.1 Environmental legislation

A comprehensive policy framework for natural resources and environmental management has been established in China since the beginning of the economic reforms in late 1970s (ADB, 2007). In 1978, the National People's Congress (NPC) added Article 26, Section 1 to the Chinese Constitution, providing that "the state protects and improves the living environment and the ecological environment, and prevents and controls pollution and other public hazards." In the same year, the NPC passed the Environmental Protection Law (EPL, for trial implementation), which required that related departments in the central government, as well as all provincial and municipal governments, to establish environmental protection institutes[25]

[25]Article 16, Chapter 3 of the EPL (1989) provides that "the local people's governments of various levels shall be responsible for the environmental quality of areas under their jurisdiction and take measures to improve the

(Golding, 2011).

The EPL came into effect in 1989 and is the main legal basis for environmental management in China nowadays. Since then, environmental legislation in China has seen a rapid expansion, particularly in the late 1990s and the beginning of the new century. A number of new environment laws were enacted, such as the Law on Environmental Impact Assessment (EIA), the Law on Cleaner Production, and the law on Circular Economy. Besides, a number of other legal acts were amended, including the EPL and the Air, Water and Waste Prevention and Control Laws. Moreover, the recently revised Criminal Law makes provisions for criminal sanctions in case of serious harm to the environment and/or natural resources (OECD, 2006).

In addition to laws, the legal statutes of environmental policy in China are supported by more than forty State Council regulations, approximately 500 standards, and more than 600 other legal or norm-creating documents, which set rules and specify tools for implementing the legislation (OECD, 2007). Furthermore, more than 1,600 regulations and administrative guidelines have been proclaimed by the sub-national people's congresses and governments (ADB, 2007). In principle, provincial governments may set more stringent standards than those already covered by the national law. Provinces can also promulgate ambient and discharge standards for pollutants that are not specified in the national law, which must be forwarded to Ministry of Environmental Protection (MEP) for review and recorded.[26] The significant variation among provincial standards is one of the evidences of the *de facto* environmental federalism.

1.3.1.2 Environmental planning

environment quality". http://www.lawinfochina.com/display.aspx?id=1208&lib=law&SearchKeyword=Environmental%20Protection%20Law&SearchCKeyword=

[26] Article 10, Chapter2 of the EPL (1989) provides that provincial "governments may establish their local standards for the discharge of pollutants for items not specified in the national standards; with regard to items already specified in the national standards, they may set local standards which are more stringent than the national standards and report the same to the competent department of environmental protection administration under the State Council for the record. Units that discharge pollutants in areas where the local standards for the discharge of pollutants have been established shall observe such local standards". http://www.lawinfochina.com/display.aspx?id=1208&lib=law&SearchKeyword=Environmental%20Protection%20Law&SearchCKeyword=.

Plans exist throughout the Chinese government. They may be national or local, comprehensive or topical (for example, focused on environment). Plans are aspirational, but also provide for required targets (Guttman and Song, 2007).[27] Developed by the Chinese government and approved by the Chinese Communist Party (CCP) and the NPC, Five-Year Plans for National Economic and Social Development (FYPs) are the basis for coordinating Chinese public policy priorities and provide key guidance to both central and sub-national authorities. Within the context of FYPs, there are a number of sectoral plans, including Five-Year Environment Plans for the environment and natural resources sectors (FYEPs). The FYEPs are further broken down into individual specific plans (e.g. for hazardous waste management, water management in key rivers and lakes, development of the environmental industry, etc.). In addition, sub-national governments prepare their own FYEPs under the guidance of national FYEPs.

Environment plans have been integrated into the FYPs since the 8th FYP (1991-1995), in which various provisions to strengthen environmental management were issued. The 9th FYEP (1996-2000) acknowledged serious deterioration of the environment and called for the establishment of environmental management and legislative systems. It also called for stricter inspection of industrial pollution control. The 10th FYEP (2001-2005) set new targets, and envisaged a number of institutional and regulatory measures such as strengthening decision-making for integration of environmental matters into economic development and promoting the use of economic instruments. The implementation of the 10th FYEP was estimated to require an investment of 1.3% of GDP (OECD, 2006); The 11th FYEP (2006-2010) was guided by the philosophy of building a resource-efficient, environment-friendly and sustainable society. Major environmental targets of the 11th FYEP include: a 20% reduction of energy consumption per unit GDP and total emission of major pollutants (i.e., COD and SO2) by 10% by 2010 compared with that of 2005. Estimated investment should account for 1.35% of GDP of the same period (The State Council

[27] The authors discuss the relation between plan and law in China. They state that plans are provided for by the Constitution and have the power of the law in many cases, however, plans have no provision for enforcement by those outside the government - citizens or NGOs, for example.

of the P.R.C., 2008); The 12th FEYP (2011-2015) was published in December, 2011. Key targets of the 12th FEYP include: an 8% reduction of COD and SO2 emissions, a 10% reduction of N-NH3 and NO_x emissions and significant improvement in ambient water and air quality (The State Council of the P.R.C., 2011). In addition, among the seven priority industries to be developed in the 12th FYP period, three sectors align with the theme of sustainable growth, i.e., energy savings and environmental protection; new energy; and clean energy vehicles (KPMG China, 2011).

1.3.1.3 Instruments

A number of specific regulatory and economic instruments are provided by Chinese environmental laws for industrial pollution control. Among various regulatory instruments introduced by the EPL (1989), one can cite three most important ones: the Discharge Permit System (DPS), the “Three Synchronizations” (“3S”) and the EIA; Economic instruments are market-based instruments with the purpose of internalizing pollution cost. Among the set of economic instruments applied in China, the most relevant one is the comprehensive system of pollution levies.

Under the DPS, enterprises which discharge pollution have to register with local Environmental Protection Bureaus (EPBs) and apply for a permit. Discharge permits are regulatory documents that limit both the quantities and concentrations of pollutants in an enterprise’s wastewater and waste gas emissions. Allocation and enforcement of discharge permits are in the charge of EPBs. It is argued that local EPBs have considerable flexibility in developing their own DPS (OECD, 2006); The “3S” system requires that the design, construction, and operation of a new industrial enterprise (or the expansion or renovation of an existing enterprise) be synchronized with the design, construction, and operation of suitable pollution control facilities (ADB, 2007). Once the construction of a project is completed, inspection and approval by environmental administrations are required for the operation of the project; The EIA is a process of identification, prediction and evaluation of a project’s potential impact on the environment and is, essentially, an aid to the decision-makers responsible for planning (Hoyle *et al.*, 1999). The Law on EIA promulgated in 2002 requires all construction projects in China be subject of EIA. The law also specifies that the content of the assessment should include identification and analysis of potential environmental impacts, possible measures to prevent or control the identified impacts, and assessment of the feasibility and costs of the possible measures. The 2002 EIA Law also requires public authorities to hold public hearings involving parties that are potentially affected (OECD, 2006).

The pollution levy system (PLS) was introduced in China as early as 1979 (OECD, 2007) and was implemented in the nationwide in 1982 (Wang and Wheeler, 2005). The PLS has seen a series of modification during the last three decades: First designed for above-standard emissions, this system was amended in the early 1990s and expanded to cover both below-standard and above-standard emissions, with higher levy rates being imposed on emissions that exceed the official standards (Wu, 2010); In 2003, the system was again amended. Since then, charges should be levied on all substances included in the emissions. Unit rates were increased and charges levied entered budgetary management; Finally, the latest modification occurred in 2008, when the amended version of the Law on the Prevention and Control of Water Pollution (LPCWP) abolished above-standard levy on waste water and converted it to administrative fines. Under the current PLS, levy rate is set by the central government, while concentration standards are set jointly by central and local governments. It is estimated that the current pollution levy system is relatively effective but some problems still exist: in particular, the charges that polluting enterprises have to pay are still significantly lower than the cost of pollution reduction (Wang and Wheeler, 2005). Moreover, in many cases, the actual charge paid by a firm is a result of bargaining with the administration (Wang *et al.*, 2003). At last but not the least, the charge collection rate is very low (OECD, 2006). Concerning other economic instruments, one can cite user charges[28], emission trading[29], and deposit-refund systems[30], etc.

[28] User charges have been applied on household and industry use of environmental services and natural resources, e.g., the wastewater treatment charge paid by all customers connected to a centralized water supply system and the fee for municipal solid waste collection.

[29] A number of pilot projects on emission trading were conducted in the 1990s. Pilot applications were organized in seven provinces in 2002 to access the feasibility of a nationwide emission trading scheme.

(OECD, 2007). The use of new economic instruments, such as environmental taxes, environmental funds, and ecological compensation funds, is proposed in the11th FYEP. Many of these new instruments are still under design (ADB, 2007).

1.3.1.4 Institutions

In China, environmental protection responsibilities are shared among different agencies and different levels of government.

The highest legislative body for environmental protection in China is the Environmental and Natural Resources Protection Committee (ERPC) under the NPC. In 1993, the Environmental Protection Committee of the NPC was established; a year later it was renamed the ERPC. The ERPC is primarily responsible for drafting, reviewing and enacting laws on environmental and natural resources protection, and overseeing their implementation. Similar committees exist at the provincial, municipal, and county levels under the respective people's congresses. These lower level committees are permitted to make their own legislation at a lower order provided it is consistent with the national legislative framework (ADB, 2007).

Policy implementation responsibilities are also divided between the center and localities. At national level, the highest administrative body for environmental protection is the MEP, under the State Council. In fact, the first administrative organ for environmental management in China - The Environmental Protection Leading Group of the State Council, was created by the government as early as 1974, in response to the first world conference on the environment held in Stockholm in 1972. After that, this organ has evolved from a department within a ministry in the 1980s, to a sub-ministry in the 1990s, then to an agency of ministry status – the State Environmental Protection Administration (SEPA) in 1998, and finally to the MEP in 2008 (ADB, 2007). According to some scholars, the stature increase of the MEP has significant meanings because it allows the ministry to regulate formerly

[30] In some provinces, monetary deposits are collected during the construction of enterprises to guarantee the application of the "Three Synchronizations". The deposit is returned to the investor if the construction satisfies the requirements. Otherwise, the deposit is retained by the environmental administration as a fine.

higher-ranking development ministries, provides long-term stability to the ministry, and allocates a vote in State Council proceedings (Qiu and Li, 2009). In resume, this stature evolution over three decades can be considered as reflect of the increasing importance that the Chinese Government attaches to environment. The wide array of responsibilities of the MEP can be summarized as follows (MEP, 2008):

- Implementing national policies and plans for environmental protection;
- Formulating environmental regulations, administrative rules, and standards;
- Organizing and supervising total emission control system and pollutant discharge license system for major pollutants;
- Review of environmental fixed-assets investment projects and arrangement of national financial budget;
- Conducting the EIA and other programs to prevent source pollution;
- Ecological conservation and nuclear safety guide and supervision;
- Environmental monitoring and information release;
- Organizing and promoting environmental R & D;
- Implementing international conventions, cooperation, and exchanges
- Promoting environmental publicity, communications work, environmental education, public participation and NGOs.

Nevertheless, the primary responsibility for environmental policies implementation is realized at the sub-national level, by more than 3000 EPBs with approximately 45000 employees in these provincial, prefectural, and county level administration bureaus.[31] Supervised by the MEP, these EPBs enforce national and provincial environmental protection laws and regulations. As the main executing agencies for environmental protection policies in China, EPBs apply different instruments and deal directly with polluters or polluting events. As a result, it is their efforts which determine the effectiveness of environmental policies in China. The main responsibilities of EPBs can be summarized as follows (ADB, 2007; OECD, 2006):

- Overseeing EIA and other procedures for new development projects, e.g., “Three

[31] 2009 data from China Environmental Yearbook (2010)

Synchronizations;

- Monitoring pollution releases from industries;
- Assessing levies for pollution discharges;
- Initiating legal action against environmental violations, such as stopping and imposing fines and penalties
- Dealing with public complaints, mediating pollution disputes, and investigating pollution accidents
- Environmental reporting, education and awareness raising activities.

1.3.2 Ineffective local enforcement and *de facto* environmental federalism

In spite of the comprehensive policy framework presented above, environmental laws and legal enforcement have failed to meaningfully address pollution problems and improve environmental quality in China. As discussed in General Introduction, poor environment quality continues to make tremendous damages to national economy, public health and eco-system.

The ineffectiveness of local enforcement is largely accepted to be the main reason for environmental policy failures in China. A joint investigation by SEPA and Ministry of Land and Resources in 2004 shows that only 30 to 40 percent of the mining construction projects went through the procedure of the EIA as required, while in some areas only 6 to 7 percent did so; Some scholars estimated that only 10% of China's environmental law is enforced in 2005.[32] In fact, even though several types of non-compliance sanctions are used by environmental authorities, a wide gap exists between what EPBs are authorized to apply and what they actually do when environmental rules are violated (OECD, 2007). Among different driving forces behind the ineffectiveness of enforcement, two essential ones can be identified:

First, many if not all EPBs lack the resources to develop the scientific, technical,

[32] Embassy of China, *China Improves Enforcement of Environmental Laws*. http://www.chinese-embassy.org.uk/eng/zt/Features/t214565.htm. .

and managerial capacity needed to effectively carry out their mission (Xue *et al.*, 2006). The lack can be either in human resources or in funding or in both. Concerning human resources, even though the number of inspectors nationwide has been multiplied during one decade (from 28039 in 1999 to 60896 in 2009),[33] the staffing is not likely to be sufficient to effectively compliance monitoring and enforcement responsibilities (Golding, 2011; OECD, 2006). Moreover, EPBs' staffs often have little or no legal training (Lan *et al.*, 2011). The municipal EPB of Shanghai, for example, has only three attorneys in 1998. In contrast, New York State, which has roughly the equivalent population of Shanghai, has ninety-eight state attorneys dedicated to environmental protection in addition to thirty-seven environmental attorneys in the attorney general's office (Golding, 2011). The lack of sufficient financial resources is also responsible for policy failures, e.g., through the lack of quality monitoring equipment. It is argued that insufficient funding has created perverse incentives with deleterious environmental impacts, in that many EPBs have become dependent on the pollution levies they collect, which yield substantial revenues and are used to cover their operating costs (Xue *et al.*, 2006). This means indirectly that EPBs have an incentive to allow industries to pollute so that they can collect pollution fees. The lack of resource and enforcement capacity has given rise to the so called "pragmatism". Pragmatism is reflected in EPBs' reliance on *guanxi*[34] with regulated enterprises (OECD, 2007). Guided by the pragmatism, considerable discretion is applied by EPBs in determining how to enforce environmental requirements (e.g. how stringent and to which enterprises). For example, pragmatic enforcement can lead EPBs to target big polluters and leave small and middle ones unattended even if the aggregated pollution of the latter can be much larger (OECD, 2006). Besides, pragmatism can lead to enforcement failures when local EPB officials want to maintain harmonious relations with regulated enterprises, especially if pollution levies are used to cover EPB's operating costs.

[33] China environment Yearbook (1999, 2009)

[34] The Chinese word *guanxi* is frequently translated as "social connections". In general, *guanxi* is maintained by trading favours over long periods. These exchanges are often viewed as creating a resource that can be used to "get things done".

Another widely recognized driving force behind weak enforcement is the local protectionism (Golding, 2011). Since EPBs are institutionally and financially subordinated to local governments, the latter may interfere with local environmental enforcement.[35] The widespread local protectionism in China had a two-part cause: on one hand, legislation in China is generally aspirational and vague, which gives great enforcement discretion to local officials; on the other hand, local officials exercise their enforcement discretion to protect local economic interests rather than implementing environmental legislative purposes (Rooij *et al.*, 2006). Local governments sometimes collude with enterprises which provide tax revenue or employment and help them to escape costly environmental requirements. For example, Dasgupta *et al.* (1997) describe that communities are reluctant in imposing regulatory costs on township-village enterprises in China

The policy failures mentioned above and their causes can be at least in part related to the *de facto* environmental federalism in China. On one hand, *de facto* environmental federalism creates strong incentives for Chinese local governments to maintain weak enforcement efforts. First, classically, environmental federalism may lead to a race-to-the-bottom in which jurisdictions compete for mobile capital by offering lower environmental standards; secondly, trans-boundary pollution problems may also conduct to ineffective enforcement effort due to pollution spillovers and free-riding behaviors, when environmental policymaking is decentralized; at last but not the least, because Chinese residents cannot move relatively freely between jurisdictions due to the household registration (*hukou*) system,[36] the classic merit of decentralization – voting with their feet (Tiebout, 1956) - doesn't hold in China, and the competition for mobile capital must dominate. On the other hand, *de facto* environmental federalism has provided Chinese localities with the possibility to apply weak enforcement. First, localities participate in setting and can have their own environmental standards; secondly, local EPBs have primary responsibilities and considerable discretion in environmental regulation enforcement, as discussed

[35] More details are given in Chapter 2.

[36] Nevertheless, it is notable that, although marginally, migration between urban areas always exist in China. Moreover, the *Hukou* system is becoming less constraining in local public good allocation.

previously in the section; finally, *de facto* environmental federalism has definitely facilitated the local protectionism.

Just as the fiscal decentralization which can create either a “helping hand” or “grabbing hand” for market development depending on whether officials benefit from their policy efforts (Jin *et al.*, 2005). *De facto* environmental federalism can also facilitate or slow environmental regulatory enforcement depending on whether officials benefit from environmental gains. In effect, since the 1978 reforms and until very recently, national development priority has always been given to economic growth over environmental protection in China. Facing the structural conflict between economic growth and environmental protection,[37] the “pro-growth” incentives, and different capacity constraints, it is not surprising that Chinese localities use the autonomy endowed by the *de facto* environmental federalism to develop economy at cost of environmental goals. It seems that given the skewed incentives, *de facto* environmental federalism has created a “grabbing hand” in the sense that it has become a tool to promote economic growth rather than environmental protection.

1.4 Concluding remarks

In a country where economic, geographical and cultural heterogeneities across regions are as great as China, it is impossible for a centrally applied uniform environmental standard to be efficient everywhere. Even in discarding the assumption of uniform standard, it must be unfeasible for the central government to obtain necessary and accurate local information in order to provide locally-adapted environmental services. As a result, the merits of decentralization seem particularly attractive and promising for China. However, as argued by Fredriksson *et al.* (2006), environmental federalism is not a panacea. Devolution of power from the center will tend to create or exacerbate problems where local officials face skewed incentives (Lan *et al.*, 2011). Effectively, decentralization can generate either a “helping hand” or a “grabbing hand” for policy goals, depending on what kind of incentive local officials confront.

[37] That is to say, economic growth generally goes against environmental protection, and *vice versa.*

In this chapter, in reviewing the *de facto* federalism in China, I show that the *de facto* environmental federalism and the one-sided fiscal decentralization are likely to work side by side in contributing to ineffective environmental regulatory enforcement at the sub-national level in this country. Under such *de facto* federalism, sub-national governments in China have not only the possibility but also strong economic incentives to conduct weak environmental regulatory enforcement. Confronting the extremely skewed pro-growth incentive, sub-national governments have probably used their autonomy in environmental policy implementation to facilitate economic growth rather than (or even in sacrificing) environmental protection.

Chapter 2 Border-effect in trans-boundary pollution: A study of polluting firms' location choice in Hebei province*

* This chapter is an adapted version of an article co-authored with Chloé Duvivier.

2.1 Introduction

In order to study empirically the effects of the *de facto* environmental federalism in China, I begin with one of the most cited shortcomings of environmental federalism, i.e. the free riding behavior in case of trans-boundary pollution.

When pollution crosses jurisdictional borders, polluting jurisdictions don't experience the full benefits of pollution control (Sigman, 2002). As a result, under environmental federalism, uncoordinated jurisdictions may engage in free-riding behaviors, leading to an excess of trans-boundary pollution (Helland and Whitford, 2003; Kahn, 2004; Konisky and Woods, 2010; Sigman, 2005). Particularly, the border-effect, i.e. an excess of pollution at jurisdictional borders, may arise. For example, Kahn (2004) shows that, in the United States, cancer rates are substantially higher in border counties than in interior ones, proving that people in border counties suffer disproportionately from trans-boundary pollution.

As discussed in Chapter 1, China has a *de facto* environmental federalism: the implementation of environmental policies is largely decentralized, and local EPBs have considerable discretion in regulatory enforcement. It seems that, in this context, free-riding behaviors and border effects are very likely to exist. In fact, since several years, more and more frequent trans-boundary pollution problems have already attracted great attention in China. The *Huai* River, which runs through four provinces (Henan, Shandong, Anhui and Jiangsu), is very illustrative. As discussed in General Introduction, on several occasions, downstream provinces accused upstream provinces of dumping pollution into the river in order to evacuate it to other provinces. In many cases, trans-boundary pollution has led to interregional conflicts which are difficult to coordinate.[38] Among different consequences of trans-boundary pollution, a serious one is the border-effect. In order to be aware of this potential risk, the MEP has in effect paid particular attention to river water quality supervision at interprovincial borders.[39]

[38] Six regional offices of the MEP have been created in part for the purpose of coordinating conflicts caused by trans-boundary pollution.

[39] A nationwide Surface Water Quality Automatic Monitoring System has been established since 1999. In 2009,

Although trans-boundary pollution has caused highlighted problems in China, very few research studies have investigated its border-effect, probably because of data unavailability. With the purpose of filling this gap in the literature, this chapter tests for the border-effect of trans-boundary pollution in studying the location choice of polluting firms between 2002 and 2008 in Hebei province. Precisely, using a unique dataset and count-data models, this chapter tests whether polluting firms are more likely to set up, *ceteris paribus*, in counties that share a border with another province than in interior counties. The rest of the chapter is organized as follows. Following the introduction, in Section 2, a brief literature is made to understand why, in the context of China's current decentralized policy, polluting firms would tend to agglomerate near borders. Section 3 is devoted to the description of the study area and data. Estimation strategy is presented in section 4 and results in section 5. Finally, I conclude and discuss the empirical results obtained in the chapter.

2.2 Literature review: why borders?

Like all plants, those which pollute do not choose their location randomly. Instead, they decide to set up in a particular region to maximize their profit.[40] Generally, firms are attracted to regions with good market opportunities, and where labor is cheap and skilled. In spite of these economic considerations, polluting firms are also likely to take into account the stringency of environmental regulation. Several studies find that China's environmental policy has significant influence on polluting firms. For example, environmental controls significantly affect the environmental performance of polluting industries in the city of Zhenjiang (Dasgupta *et al.*, 2001); Other studies find that the pollution levy system has a significant impact on the level of industrial pollution (Wang and Wheeler, 2003) and on the waste water treatment expenditure (Wang, 2002); Although state-owned enterprises have more bargaining power with

100 automatic stations report water quality along main rivers and lakes across China. Particularly, 37 stations are set where rivers cross provincial borders, in order to supervise trans-boundary pollution (China Environment Yearbook, 2010).

[40] Several studies show that in China, the location choice of both foreign (He, 2003; Wu, 1999) and Chinese firms (Wen, 2004) depends nowadays on "rational economic considerations".

local authorities in terms of levies (Wang, *et al.*, 2003), environmental policy also has a significant impact on them (Wang and Wheeler, 2005).

In the Chinese context, where the implementation of environmental policy is decentralized, it is expected that border effect may also matter for polluting firms. Under this assumption, border counties would constitute particularly attractive destinations for polluting firms within a province. Precisely, two rationales could explain why polluting firms set up near borders, i.e. "pollution havens" and "free-riding" hypotheses.

2.2.1 Interprovincial stringency difference: "pollution havens hypothesis"

As discussed in Chapters 1, in China, the stringency of environmental regulation is to a great extent to the discretion of provinces and varies greatly from one province to another (see Chapter 3 for more details). These regional differences would be at the origin of a "pollution havens" phenomenon within the country,[41] i.e., polluting firms would be attracted to regions where environmental regulations are less strict (Dean *et al.*, 2009; He, 2006).

Effectively, it would be profitable for a firm to locate just at the border between two provinces if there are discontinuities in environmental regulations at border, i.e., one can move suddenly from a stricter environmental regulation to a less restrictive one by crossing the administrative boundary. In this case, crossing a border can therefore be a way to escape from severe environmental regulations of the neighboring province while continuing to benefit from its market access. Kahn (2004) shows that, in low environmental regulation states of the U.S., dirty industries set up more in counties that border high regulation states than in interior counties.

Nevertheless, this kind of border-effect could be limited in China because of a

[41] The hypothesis of "pollution havens" is commonly considered at international level. According to this hypothesis, in a world of free trade, the South, whose environmental regulations are less stringent, has a comparative advantage in producing "dirty" goods and attracts polluting industries to migrate from the North.

significant interprovincial protectionism. It is argued that under such protectionism, domestic market is fragmented along provincial borders and inter-provincial trade barriers are set to protect local industry (Poncet, 2003; Poncet, 2005; Young, 2000). With intense interprovincial protectionism, it would be no more profitable for a firm to locate in a border county because crossing the border means a loss of market access.

2.2.2 Intra-provincial stringency difference: "free-riding hypothesis"

Polluting firms would also be attracted to border counties due to intra-provincial stringency difference. In effect, regional regulators may implement environmental policy less strictly in border counties than in interior ones (Helland and Whitford, 2003). Several elements could encourage them to do so.

First of all, at borders, a region's expenditure on pollution control does not solely benefit itself but also its neighbor regions due to pollution spillovers. Since regions have limited financial resources, they would prefer spending them where they can fully enjoy them, i.e., in interior counties. Thus the positive externality of expenditure on environmental protection makes that it would be below the optimal level in border counties.

Secondly, at borders, a firm's pollution can partly fall on the neighboring region. Thus, in border counties, the region may enjoy the overall positive economic benefit related to the presence of the firm (e.g. taxes) and suffer from only a part of its pollution. On the contrary, in interior counties, the region has to bear much more, if not all of the pollution. As a result, in the presence of pollution’s negative externality, pollution discharged in border counties would be greater than the optimal level. This free-riding phenomenon can explain why, in the U.S., plants whose pollution falls partly on the population of neighboring states tend to pollute more (Gray and Shadbegian, 2004).

In the Chinese context, given the severe fiscal pressure confronted by provinces, it is not surprising that provincial regulators would care more about interior counties than border ones. Moreover, it is expected that social discontent related to polluting firms would be higher in interior counties than in border ones. Given the increasing public participation in environmental issues,[42] a regulator concerned with his political support would be more likely to guide polluting firms towards the border.

2.3 Description of the study area and data

2.3.1 Hebei province

This study is carried out in Hebei Province for several reasons. First of all, since the very beginning of China's industrialization in the early 1950s, Hebei has been specialized in heavy industries. The long history of industrialization makes it one of the most polluted provinces in the country. According to the list of the most polluting firms published in 2010 by the MEP, Hebei is one of the provinces which have the largest number of polluting firms. Among the 9833 top polluters in China, 744 are located in Hebei, just behind Jiangsu (838) and Shandong (774). Then, Hebei shares borders with seven other provinces including the centrally administrated municipalities of Beijing and Tianjin (see Figure 2.1). Moreover, Hebei has already been involved in several conflicts of trans-boundary pollution. For example, in January 2008, residents of *Wuqing* district (Tianjin) complained that a cement plant of the neighbor *Xianghe* county (Hebei) over-discharged soot pollution which crossed the provincial border and damaged their soil and crop production;[43] In August 2010, residents of the city of Chifeng (Inner Mongolia), located downstream on the *Xiluga* river, registered a complaint against a firm in the upstream county of Weichang (Hebei). According to the inhabitants of Chifeng, the firm dumped untreated sewage into the river which would have resulted in the death of their livestock.[44] Finally, Hebei is chosen because it is one of the few provinces whose data are available to

[42] Discussed in more details in Chapter 4
[43] Document No.3, 2008, EPB of Wuqing district, Tianjin city, http://gk.tjwq.gov.cn/ConInfoParticular.jsp?id=1364.
[44] China Environment News, November 23th 2010. http://www.022net.com/2010/11-23/495144333266320.html.

carry out this study.

Regarding the environmental regulatory enforcement, in 2002, Hebei had an average pollution levy charge of about 7300 yuan per polluting facility, which was very similar to the national average level. In 2008, the average charge rose to about 30500 yuan per polluting facility. These data highlight that the environmental policy has been tightened over the period.[45]

Figure 2.1: Hebei province: county level divisions

2.3.2 Dependent variable and construction of the sample

The dependent variable to be estimated is the number of polluting firms created by county[46] and by year over the period 2002-2008. This variable is constructed from the lists published by the MEP and the EPB of Hebei. In fact, since 2007, the MEP and

[45] Data calculated based on China Environment Yearbook (2002; 2008)
[46] The province of Hebei counts 172 county level divisions including 36 districts, 22 county-level cities and 114 counties. Because disaggregated data for the districts of the 11 prefectural-level cities are not available, the districts of a same prefectural-level city are aggregated. That's why the sample contains147 cross-sectional units. In the list of polluting firms, there are public ones, private ones and collective ones. The FDIs are also included.

provincial EPBs have annually published lists (*Guojia zhongdian jiankong qiye mingdan* and *Sheng zhongdian jiankong qiye mingdan*) that identify the most polluting firms in China (and in each province).[47] These lists report the name of each firm and the county in which it is located. However, information is neither provided on the date of creation nor on emission level.

Although these lists provide necessary information to estimate a “model of stock” in which the total number of firms in a county is regressed on a set of characteristics of the county (see Ma (2010) for example), such a model is not reliable to the present location choice study. Actually, what is needed here is a “flow model” in which the number of firms created in a county in the year t is regressed on the characteristics of this county in year t (or $t-1$). The reasons are as follows: first of all, the characteristics of the county in year t cannot determine the location choice of firms before that year. Then, some firms in the lists were created between 1953 and 1978. During that period of time, unlike more recently, the setting up of a firm didn't depend on an economic rationale (Wen, 2004). It would be therefore impossible to explain within the same model the location of firms created before and after the 1980s. At last but not the least, there was no environmental policy framework in China before 1979. As a result, in order to test for the border-effect related to trans-boundary pollution, one has to take a sample of recently created firms which are supposed to be sensitive to environmental regulation.

In order to estimate a “flow model”, creation dates of polluting firms are collected on the official website of the Industrial and Commercial Bureau of Hebei province.[48] Once the creation dates are obtained, firms created after 2002 are selected, the year from which data for the explanatory variables are available. Because the last list of polluting firms was published in 2010 and lists the most polluting firms in 2008, the final sample covers the 147 counties of Hebei over the period 2002-2008.

[47] These lists identify the most polluting firms at national and provincial level in terms of air, water and sewage pollution. More precisely, the identified firms produce 65% of total industrial emissions of SO2, NOx, COD, NH3-N and heavy metals in China. Note that there is a lag of two years between the census of firms in the list and their pollution. Thus, the list of 2007 lists the firms that polluted the most in 2005. http://www.mep.gov.cn/info/bgw/bbgtwj/ for National lists; http://www.hb12369.net for provincial lists of Hebei

[48] http://www.222.223.188.6/wsgs/ywztcx/query.asp.

2.3.3 Variables of interest

Three variables of interest are constructed to ensure the robustness. Firstly, in following the literature (Helland and Whitford, 2003; Kahn, 2004; Konisky and Woods, 2010), a dummy variable (*Border*_1) is created. *Border*_1 is equal to 1 if the county shares a border with another province or the sea, and 0 otherwise.

However, as showed in Figure 2.1, among border counties, some share a very small part of their border with another province while others share more than half of the total length of their border with another province. One may expect that the border effects would be stronger in the latter case than in the former case. To take into account this variability among border counties, a second variable (*Border*_2) is created: *Border*_2 is equal to the length of the common border between a county and another province (or the sea) divided by the total length of this county's border.

Nevertheless, both *Border*_1 and *Border*_2 have an important drawback in that they do not take into account the variability between non-border counties. In fact, among interior counties, some are located at the center of the province whereas others are very close to the borders. Naturally, one may think that the border-effect may also exist for the latter category, even if they don't really touch the provincial border. That is why, a third variable *Distance* is created, which is equal to the distance between the county seat and the closest provincial border.

All three variables are constructed with the GIS data of the Chinese Academy of Sciences[49] using ArcGis 9.2. If the border-effect exists, coefficients associated with variables *Border* 1 and *Border* 2 will be positive, while the coefficient associated with *Distance* will be negative.

2.3.4 Some descriptive statistics

Tables 2.1 and 2.2 give some descriptive statistics on the polluting firms in Hebei identified in the lists of the MEP and the EPB. Table 2.1 reports the stock of firms per

[49] County border database, Thematic Database for Human-Earth System, the Chinese Academy of Sciences, http://www.data.ac.cn/jieshao.asp

100 km^2 in 2002 and 2008. It is notable that non-border counties have a larger number of polluting firms per km^2 than border counties both in 2002 and in 2008. *A priori*, this contradicts the border-effect hypothesis.

Table 2.1: Stock of polluting firms per km^2 in 2002 and 2008

	Number of counties	Stock of firms per 100 km^2 in 2002	Stock of firms per 100 km^2 in 2002
All counties	147	0.85	1.15
Border counties	66	0.54	0.76
Non- border counties	81	1.10	1.47

Table 2.2: Creation of polluting firms between 2002 and 2008

	Number of counties	Firms created per county	Firms created per 100 km^2	Firms created per 100 inhabitants
All counties	147	4.57	0.46	12.68
Border counties	66	7.15	0.51	22.32
Non- border counties	81	2.47	0.41	4.82

However, according to Table 2.2, during the more recent period, more polluting firms have been created in border counties than in interior ones. The difference between Table 2.1 and Table 2.2 reflects an evolution of polluting firms' location choice in Hebei. As stated previously, among the firms identified in the lists, some were created before the 1980s. In that era, firms' location decision did not depend on an economic rationale but arose from a strategy which aimed at protecting industries from potential destructive military conflicts. It is argued that three principles determined the location of industrial firms from 1965 to 1978, i.e. "proximity to mountains, dispersion and concealment" (Wen, 2004). As a result, industrial firms were located far away from the coast. Moreover, before 1978, the environmental policy framework wasn't established in China thus couldn't affect firms' location choice. Therefore, it is not surprising that the stock of the most polluting firms is not higher in border counties than in non-border counties. In contrast, newly created polluting firms choose their location according to economic criteria and are very likely to take into account the difference in environmental stringency (see Section 1). Table 2.2 suggests that the border-effect of trans-boundary pollution is very likely to exist in Hebei between 2002 and 2008.

2.3.5 Other determinants in polluting firms' choice of location

Traditional determinants of firms' location, i.e. regional characteristics that may affect firms' profit, are introduced as control variables.

On one hand, a number of variables can affect firms' benefits. First of all, firms are attracted to regions with agglomeration economies. Two indicators are constructed to capture this effect, i.e. agglomeration economies in the industry sector and agglomeration economies in the service sector (description and definition of variables are given in Appendices 2.1 and 2.2). Then, firms are more likely to set up in regions that offer significant market opportunities. As firms do not only consider the local market but also the markets of neighboring regions (Head and Mayer, 2004), two variables are used to capture the effects of local and external markets, respectively. Moreover, an indicator of education level is introduced for each county because well educated population is likely to attract firms. Furthermore, a dummy variable is also created to control for the presence of Special Economic Zone (SEZ) in each county because regions benefiting from SEZ status attract significantly more firms in China (Cheng and Stough, 2006; Wu, 1999). Finally, GRP per capita and its squared term is included to check the existence of the Environmental Kuznuts Curve (EKC).

On the other hand, firms are attracted by regions with cheap production factors. As a result, the real wage rate in industry and the population density are introduced as proxies for labor and land price. Note that polluting firms would also prefer areas with low population density to minimize social discontent. In addition, dummies are introduced to capture the nature of the administrative unit (county, district or city at county level) and time fixed effects. All variables are constructed with data published in Hebei Statistical Yearbook (2003-2009).

2.4 Estimation strategy

It is notable that the dependent variable in the present study, the number of polluting firms created in each county, is composed of non-negative integers with high frequency of zeros. This special nature leads to the adoption of a count-data model.[50] The standard model in this case is the Poisson regression model. This model estimates how much a 1% change in an explanatory variable x_i affects the probability that a firm sets up in the territory i. The probability, $Prob(y_i)$, of a territory i to receive y_i firms is based on a set of characteristics x_i of this territory as formed in (2.1):

$$\Pr ob(y_i) = f(x_i) \tag{2.1}$$

The most common way to model this probability function is to assume that the variable y_i follows a Poisson distribution. In this case, the probability for a region i to receive y_i firms is given by (2.2):

$$\Pr ob(Y = y_i \mid x_i) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!}, y = 0,1,2,...,n \text{ and } \ln(\lambda_i) = \beta' X_i \tag{2.2}$$

where the vector of coefficients β is estimated by the method of the maximum likelihood. However, the Poisson model is restrictive because it assumes that λ_i is both the conditional mean and variance of y_i (hypothesis of equi-dispersion), as shown in (2.3):

$$Var[y_i \mid x_i] = E[y_i \mid x_i] = \lambda_i \tag{2.3}$$

[50] Most recent studies on firms' location choice prefer to use a count data model than a discrete choice model (Arauzo - Carod *et al.*, 2010). First, the discrete choice model meets computational difficulties when the number of potential locations is large, which is the case of this study. More importantly, the discrete choice model imposes a very restrictive assumption of "Independence of Irrelevant Alternatives" (IIA), which is considered to be too strong for this study.

Unfortunately, the hypothesis of equi-dispersion is generally poorly respected with data on firms' location choice as the conditional variance is often higher than the conditional mean, which is called over-dispersion (Cameron and Trivedi, 1998). In practice, several phenomena can lead to over-dispersion, in particular the clustering of firms due to agglomeration effects and the presence of unobserved heterogeneity. In case of over-dispersion, the Poisson model is no more appropriate because standard deviations obtained are biased and therefore, statistical inferences are invalid. The standard way to address over-dispersion is to assume that y_i follows a negative binomial distribution, which is more flexible than the Poisson distribution. The negative binomial model (NBM) is obtained in (2.4), by introducing heterogeneity in the Poisson parameter:

$$\ln(\lambda_i) = \beta' X_i + \varepsilon_i \tag{2.4}$$

where ε_i follows a gamma distribution with mean 1 and variance α. In this model mixed of Poisson and Gamma distributions, the probability $Prob(y_i)$ of a territory i to receive a number y_i of firms is given by (2.5):

$$\Pr ob(Y = y_i) = \frac{\theta^{\theta} \lambda_i^{y_i}}{\Gamma(y_i + 1)\Gamma(\theta)} \frac{\Gamma(y_i + \theta)}{(\lambda_i + \theta)^{y_i + \theta}} \tag{2.5}$$

where Γ is the gamma function and $\theta = \frac{1}{\alpha}$, with α the over-dispersion parameter. When $\alpha = 0$, there is equi-dispersion and the NBM is equivalent to the Poisson model. (The two models are nested.) The vector of the coefficients β is always estimated by the method of the maximum likelihood. Note that in the NBM, the variance can be different from the mean because it is linked to the mean by the over-dispersion parameter α which has to be estimated in (2.6):

$$Var[y_i \mid x_i] = E[y_i \mid x_i]\{1 + \alpha E[y_i \mid x_i]\} > E[y_i \mid x_i] \tag{2.6}$$

Poisson and negative binomial models can be estimated with panel data. Hausman *et al.* (1984) propose estimators with fixed effects and random effects for Poisson and negative binomial models. The Poisson (or negative binomial) model with random effects is asymptotically more efficient than the fixed-effect model. However, in case of correlation between explanatory variables and fixed effects, the random-effect model is not consistent. As for linear panel, the lack of correlation between explanatory variables and specific effects can be tested with the Hausman test.

One difficulty arises with the present panel dataset. In fact, the variables of interest in the present study are geographical variables, thus constant over time. To the knowledge of the author, it is impossible to estimate the coefficients associated with time invariant variables using count data model with fixed-effects. Moreover, it is impossible to interpret the Hausman test to check whether the random-effect model is appropriate because the fixed-effect model does not converge. As a result, the estimation of the random effects model may produce potentially biased estimates. In order to test for the robustness of the random-effect model results, cross-sectional estimate has been run in addition to the random-effect estimate. In this case, the total number of polluting firms created in each county between 2002 and 2008 is regressed against the average values of the explanatory variables of this period. The advantage of panel estimation is that one can test for the evolution of the border effects over time. In effect, the period of 2002-2008 has seen a series of changes, e.g. the tightening of the environmental policy, the increasing number of public complaints, and the creation of regional offices of the MEP. It is possible that these events have affected behaviors of local governments and polluting firms during this period.

2.5Estimation results and discussion

2.5.1 Poisson model or NBM?

The first step is to check if the Poisson model fits the dataset. To this end, the hypothesis of equi-dispersion is tested in several ways. First of all, the standard deviation of the dependent variable is more than two times its mean, which indicates that there is probably over-dispersion (see Appendix 2.1). Secondly, the model is estimated in assuming that the number of created enterprises follows a Poisson distribution.[51] The goodness-of-fit test statistic is always significant, suggesting that the Poisson regression model is inappropriate. As a result, the model is estimated assuming that the dependent variable follows a negative binomial distribution.

2.5.2 Border-effect of trans-boundary pollution?

Table 2.3 presents cross-sectional estimates (1), (2) and (3), with the three variables of interest respectively. Tables 2.4 and 2.5 report panel estimates (4) to (9). Among the panel estimates, first, the number of firms created in year *t* is regressed against values of the explanatory variables in *t*: estimations (4), (5) and (6). Secondly, lagged explanatory variables are used in order to rule out endogeneity: estimations (7), (8) and (9).

In all nine cases, the coefficients associated with variables of interest have the expected signs and are statistically significant. Counties that share a (larger part of their) border with another province or with the sea have a higher probability to receive polluting firms. In the same way, the farther the county seat is from the provincial boundary, the lower its probability to receive polluting firms is. These results provide evidence of border-effect related to trans-boundary pollution in China. If this has already been demonstrated in the U.S. case, to the knowledge of the author, this is the first study to demonstrate this phenomenon in China.

[51] Results for cross-sectional Poisson regressions are reported in Appendix 2.3. Note that despite the unfitness of the Poisson model, results regarding the variables of interest are always robust.

Table 2.3: Cross-sectional estimates of the NBM

	(1)		(2)		(3)	
Border_1	0.570*	(0.059)				
Border_2			2.519***	(0.003)		
Distance					-0.331**	(0.033)
Agglo. industry	-0.322	(0.262)	-0.341	(0.223)	-0.367	(0.198)
Agglo. service	2.271**	(0.011)	1.986**	(0.015)	2.273***	(0.008)
Population density	-2.155***	(0.005)	-1.931**	(0.010)	-2.314***	(0.002)
Wage	-3.210***	(0.009)	-3.241***	(0.007)	-3.406***	(0.007)
Education	-0.659	(0.395)	-0.431	(0.551)	-0.471	(0.533)
Local market	1.502***	(0.004)	1.533***	(0.003)	1.599***	(0.002)
External market	-0.556***	(0.000)	-0.507***	(0.000)	-0.529***	(0.000)
SEZ	0.128	(0.564)	0.0545	(0.800)	0.113	(0.622)
County	1.977	(0.141)	1.346	(0.270)	1.637	(0.187)
County level city	1.966	(0.134)	1.331	(0.256)	1.656	(0.173)
GRP per cap.	0.938**	(0.028)	1.007**	(0.019)	1.025**	(0.013)
Sq. GRP per cap	-0.0917	(0.811)	-0.107	(0.771)	-0.117	(0.760)
Constant	31.25***	(0.007)	31.80***	(0.004)	38.15***	(0.002)
Alpha	0.194	(0.260)	0.119	(0.495)	0.179	(0.299)
N	147		147		147	

Note: P-values in parenthesis: * p<0.1, ** p<0.05, *** p<0.01

Table 2.4: Random-effect estimates of the NBM
(with contemporaneous variables)

	(4)		(5)		(6)	
Border_1	0.550**	(0.032)				
Border_2			1.954***	(0.003)		
Distance					-0.205*	(0.096)
Agglo. industry	0.103	(0.417)	0.100	(0.427)	0.094	(0.463)
Agglo. service	1.078**	(0.019)	1.013**	(0.026)	1.056**	(0.021)
Population density	-1.138**	(0.013)	-1.108**	(0.014)	-1.279***	(0.004)
Wage	-0.834	(0.108)	-0.887*	(0.085)	-0.874*	(0.093)
Education	0.013	(0.970)	0.023	(0.946)	0.027	(0.937)
Local market	0.948***	(0.002)	0.967***	(0.001)	1.030***	(0.001)
External market	-0.618***	(0.000)	-0.581***	(0.000)	-0.594***	(0.000)
SEZ	-0.081	(0.620)	-0.052	(0. 741)	-0.057	(0.726)
County	1.529*	(0.094)	1.425	(0.114)	1.408	(0.124)
County level city	1.308	(0.129)	1.202	(0.157)	1.161	(0.175)
GRP per cap.	0.419	(0.135)	0.438	(0.116)	0.480*	(0.087)
Sq. GRP per cap	-0.499***	(0.000)	-0.504***	(0.000)	-0.500***	(0.000)
Constant	9.227*	(0.067)	9.535*	(0.054)	12.660**	(0.013)
a	1.310***	(0.000)	1.344***	(0.000)	1.291***	(0.000)
b	0.271	(0.181)	0.354*	(0.092)	0.263	(0.191)
N	1029		1029		1029	

Note: P-values in parenthesis: * p<0.1, ** p<0.05, *** p<0.01. In each regression, year dummies are introduced.

Table 2.5: Random-effect estimates of the NBM (with lagged explanatory variables)

	(7)		(8)		(9)	
Border_1	0.689**	(0.017)				
Border_2			2.643***	(0.000)		
Distance					-0.233*	(0.083)
Agglo. industry	0.140	(0.318)	0.130	(0.345)	0.132	(0.348)
Agglo. service	0.275	(0.500)	0.230	(0.559)	0.287	(0.470)
Population density	-0.374	(0.386)	-0.365	(0.373)	-0.611	(0.134)
Wage	-1.088*	(0.061)	-1.149**	(0.046)	-1.144*	(0.050)
Education	-0.239	(0.523)	-0.199	(0.587)	-0.208	(0.578)
Local market	0.653**	(0.040)	0.701**	(0.023)	0.770**	(0.015)
External market	-0.610***	(0.000)	-0.561***	(0.000)	-0.579***	(0.000)
SEZ	0.145	(0.459)	0.150	(0.416)	0.181	(0.352)
County	1.030	(0.286)	0.856	(0.365)	0.907	(0.345)
County level city	0.979	(0.280)	0.821	(0.352)	0.808	(0.367)
GRP per cap.	0.470	(0.140)	0.467	(0.138)	0.524*	(0.100)
Sq. GRP per cap	-0.405**	(0.010)	-0.430***	(0.007)	-0.417***	(0.009)
Constant	9.972*	(0.077)	10.40*	(0.060)	14.28**	(0.013)
a	1.352***	(0.000)	1.422***	(0.000)	1.331***	(0.000)
b	0.125	(0.560)	0.234	(0.295)	0.104	(0.622)
N	882		882		882	

Note: P-values in parenthesis: * p<0.1, ** p<0.05, *** p<0.01. In each regression, year dummies are introduced.

Regarding the control variables, their signs and significance are coherent and relatively robust. Counties with a more developed tertiary sector, a lower population density, lower labor costs and a larger local market attract more polluting firms. These results confirm that the location choice of Chinese firms does depend on economic factors during the period of study.

2.5.3 Has the border-effect increased over time?

In order to study whether polluting firms increasingly set up in border counties over time, an interactive variable *"variable of interest * year"* is introduced into the model. Table 2.6 reports the estimation results for the interactions. Complete results can be found in Appendix 2.4. As in the last subsection, two types of panel estimates are performed: in estimations (10), (11) and (12), the dependent and the explanatory variables are contemporaneous, while lagged explanatory variables are used in estimations (13), (14) and (15). Results of these estimations suggest that border counties have become increasingly attractive destinations over the period of 2002-2008. In effect, while the variables of interest are either insignificant or not robust during the first years of the sample, they become significant and their coefficients increase over time.

Several elements can explain the increasing attractiveness of border counties: first of all, environmental policy in China has been tightened during the study period, which could have led to a perverse effect. With the tightening of environmental regulations, it is expected that polluting firms are increasingly sensitive to environmental regulations. Thus, it is possible that firms care more and more about interprovincial or intra-provincial differences in environmental standard enforcement, and as a result, are more and more attracted to border counties. Then, the Beijing Olympics Games in 2008 had led to the relocation of a large number of polluting firms. In fact, some polluting firms located in Beijing had been closed and re-opened in the neighboring province of Hebei. The Olympic Games had also made the creation of polluting firms in Beijing more difficult. It is possible that firms wishing to set up in Beijing moved to Hebei and set up as close as possible to the capital (e.g. in the counties sharing a border with it) for market access. Finally, the increasing public participation (e.g. the number of citizen complaints) regarding pollution could have induced local regulators to harden the environmental policy enforcement particularly in interior counties and lead more pollution firms toward the borders.

Table 2.6: Evolution of the border-effect over time

	(10)	(11)	(12)	(13)	(14)	(15)
	with contemporaneous variables			with lagged explanatory variables		
	Border_1	Border_2	Distance	Border_1	Border_2	Distance
Var_interest*2002	0.0473	0.262	0.0196	0.160	0.144	0.332*
	(0.890)	(0.773)	(0.916)	(0.649)	(0.880)	(0.092)
Var_interest*2003	0.168	0.201	0.307	0.852**	2.594***	-0.260
	(0.614)	(0.826)	(0.111)	(0.033)	(0.008)	(0.184)
Var interest*2004	0.838**	2.648***	-0.301	0.294	2.068**	-0.204
	(0.027)	(0.005)	(0.116)	(0.441)	(0.039)	(0.313)
Var_interest*2005	0.324	2.040**	-0.214	1.151***	4.589***	-0.498**
	(0.377)	(0.037)	(0.276)	(0.007)	(0.000)	(0.014)
Var_interest*2006	1.159***	4.490***	-0.501***	1.515***	5.803***	-0.663***
	(0.005)	(0.000)	(0.010)	(0.004)	(0.000)	(0.002)
Var interest*2007	1.491***	5.797***	-0.634***	1.364***	5.309***	-0.550***
	(0.004)	(0.000)	(0.002)	(0.005)	(0.000)	(0.009)
Var interest*2008	1.277***	5.144***	-0.524**			
	(0.008)	(0.000)	(0.011)			
N	1029	1029	1029	882	882	882

Note: P-values in parenthesis: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

2.5.4 Robustness checks

2.5.4.1 Border-effect or access to international markets?

Following the literature, in above analysis, a county is considered as a border county if it shares a common border either with another province or with the sea. However, if polluting firms set up more in coastal counties in order to benefit from a good access to international markets, the border-effect found above would not be due to trans-boundary pollution. To check if the border-effect is due to trans-boundary pollution or to international market access, the variables of interest (*Border* 1 and

Border 2) are disaggregated into two variables: "terrestrial border county" for counties that borders another province and "coastal county" for those bordering the Yellow Sea. If polluting firms set up in border counties only to benefit from a good access to international markets, the coefficient associated with the variable *terrestrial border* should not be significantly different from zero. However, if the variable *terrestrial border* remains significant, it confirms the trans-boundary pollution hypothesis. The results of the estimations (16) - (21), reported in Tables 2.7 and 2.8, validate the trans-boundary pollution hypothesis. In five of the six estimations, the coefficients associated with the variable *terrestrial border* are positive and statistically significant, i.e., counties that share a (larger part of their) border with another province have a higher probability of receiving polluting firms.

2.5.4.2 "Zero inflation problem"

Count-data models allow for estimating models where the dependent variable takes the value “zero” many times. However, sometimes the dependent variable y_i takes the value “zero” more times than what is assumed by the Poisson or the negative binomial distribution. This is known as a "zero inflation problem". This problem arises when two different phenomena lead the dependent variable to take the value “zero” (for a formal presentation of the model see Greene (1994)). An excess of zeros may lead to biased results. The appropriate model to address the "zero inflation problem" is a zero-inflated model.

As shown in Table 2.9, in Hebei province from 2002 to 2008, 36 counties didn’t see polluting firms set up, which represent about 25% of the sample. The frequency of zeros is relatively low compared to studies estimating a zero-inflated model (List, 2001; Roberto, 2004).

Table 2.7: Border effects or access to international markets (cross-section estimates)

	(16)		(17)	
	Border_1		Border_2	
Terrestrial border county	0.565*	(0.077)	2.628***	(0.006)
Coastal county	0.665	(0.157)	1.729	(0.312)
Agglo. industry	-0.303	(0.278)	-0.353	(0.205)
Agglo. service	2.133**	(0.017)	2.014**	(0.015)
Population density	-1.984**	(0.010)	-1.952**	(0.011)
Wage	-3.056**	(0.017)	-3.400***	(0.009)
Education	-0.720	(0.360)	-0.501	(0.504)
Local market	1.496***	(0.003)	1.538***	(0.003)
External market	-0.571***	(0.000)	-0.496***	(0.000)
SEZ	0.086	(0.705)	0.035	(0.872)
County	1.954	(0.139)	1.301	(0.278)
County level city	1.814	(0.158)	1.281	(0.266)
GRP per cap.	0.929**	(0.033)	1.069**	(0.018)
Sq. GRP per cap	-0.073	(0.855)	-0.081	(0.826)
Constant	29.070**	(0.011)	33.120***	(0.005)
Alpha	0.176	(0.324)	0.115	(0.510)
N	147		147	

Note: P-values in parenthesis: * p<0.1, ** p<0.05, *** p<0.01.

Table 2.8: Border effects or access to international markets (panel estimates)

	(18)		(19)		(20)		(21)	
	With contemporaneous variables				With lagged explanatory variables			
	Border_1		Border_2		Border_1		Border_2	
Terrestrial border c.	0.544	(0.144)	1.667**	(0.017)	0.877**	(0.034)	2.396***	(0.002)
Coastal county	1.589**	(0.020)	4.069**	(0.020)	2.223***	(0.004)	4.786**	(0.013)
Agglo. industry	0.105	(0.404)	0.107	(0.395)	0.150	(0.278)	0.139	(0.310)
Agglo. service	1.071**	(0.021)	0.992**	(0.030)	0.220	(0.582)	0.203	(0.605)
Population density	-1.100**	(0.017)	-1.058**	(0.019)	-0.228	(0.596)	-0.305	(0.458)
Wage	-0.650	(0.213)	-0.683	(0.194)	-0.832	(0.156)	-0.959	(0.105)
Education	0.057	(0.867)	0.0744	(0.826)	-0.185	(0.623)	-0.150	(0.687)
Local market	0.999***	(0.001)	1.001***	(0.001)	0.707**	(0.025)	0.731**	(0.018)
External market	-0.654***	(0.000)	-0.615***	(0.000)	-0.661***	(0.000)	-0.594***	(0.000)
SEZ	-0.0614	(0.712)	-0.0359	(0.822)	0.128	(0.516)	0.164	(0.376)
County	1.717*	(0.061)	1.570*	(0.085)	1.252	(0.195)	1.002	(0.293)
County level city	1.376	(0.110)	1.327	(0.123)	1.033	(0.248)	0.943	(0.288)
GRP per cap.	0.297	(0.312)	0.312	(0.290)	0.306	(0.353)	0.340	(0.306)
Sq. GRP per cap	-0.488***	(0.000)	-0.514***	(0.000)	-0.392**	(0.012)	-0.439***	(0.006)
Constant	7.243	(0.157)	7.437	(0.147)	6.787	(0.240)	8.372	(0.146)
a	1.322***	(0.000)	1.348***	(0.000)	1.386***	(0.000)	1.432***	(0.000)
b	0.280	(0.171)	0.334	(0.112)	0.128	(0.533)	0.219	(0.329)
N	1029		1029		882		882	

Note: P-values in parenthesis: * p<0.1, ** p<0.05, *** p<0.01. In each regression, year dummies are introduced.

However, to be sure to obtain consistent estimates, the presence of zero inflation is tested with the Vuong (1989) test. This test allows testing for whether the zero-inflated negative binomial model (ZINBM) is more appropriate than the negative binomial model (NBM). Table 2.10 gives the values obtained from the Vuong test.

Table 2.9: Distribution of firm creations

Number of creations	0	1	2	3	4	5	>5
Frequency	36	43	24	12	8	3	21
Percentage	24.49	29.25	16.33	8.16	5.44	2.04	14.29

N.B.: The table gives the frequency and the percentage of counties with 0, 1, 2, … , >5 creations of firms from 2002 to 2008.

Table 2.10: Vuong test statistics

Variable of interest	Cross-section	Panel	
		Contemporary variables	Lagged explanatory variables
Border1	No convergence	-2.46	-2.02
Border2	No convergence	-2.28	-1.47
Distance	No convergence	-2.61	-1.81

N.B.: The model estimated in the first step is a logit model

The Vuong test does not favor in any case the zero inflated model, in that the value obtained is never higher than 1.96.[52] The test clearly rejects the ZINBM in favor of the NBM when the model is estimated in panel with contemporaneous variables. However, it fails to conclude in favor of one or the other model when estimating in panel with lagged explanatory variables. As a result, the estimation results of the ZINBM model in panel with lagged explanatory variables ((22), (23), and (24)) are presented in Table 2.11. According to Table 2.11, taking into account the potential problem of zero-inflation does not change the previous results because the coefficients associated with variables of interest still have expected sign and significance.

[52] Asymptotically, the Vuong test statistics have a standard normal distribution and hence, the test statistics obtained have to be compared with the critical value of the normal distribution (1.96). A value above 1.96 (below -1.96) rejects the NBM (ZINBM) in favor of the ZINBM model (NBM). For panel data, this test exists only in pooling.

Table 2.11: ZINBM with lagged explanatory variables

	(22)		(23)		(24)	
Border_1	0.664***	(0.005)				
Border_2			2.896***	(0.000)		
Distance					-0.112**	(0.016)
Agglo. industry	-0.013	(0.909)	-0.034	(0.764)	-0.044	(0.742)
Agglo. service	1.136***	(0.003)	1.004**	(0.011)	1.271***	(0.002)
Population density	-1.209***	(0.001)	-1.091***	(0.004)	-1.470***	(0.000)
Wage	-1.195*	(0.077)	-1.158*	(0.076)	-1.153	(0.123)
Education	-0.197	(0.638)	-0.087	(0.838)	-0.141	(0.773)
Local market	0.737***	(0.010)	0.801***	(0.005)	0.862***	(0.005)
External market	-0.433***	(0.000)	-0.381***	(0.000)	-0.426***	(0.000)
SEZ	0.278	(0.173)	0.256	(0.167)	0.349	(0.131)
County	1.527*	(0.075)	1.126	(0.179)	1.675*	(0.075)
County level city	1.728**	(0.028)	1.379*	(0.071)	1.949**	(0.024)
GRP per cap.	0.063	(0.831)	-0.013	(0.964)	0.016	(0.962)
Sq. GRP per cap	-0.367	(0.114)	-0.413*	(0.090)	-0.423	(0.103)
Constant	12.102*	(0.057)	11.594*	(0.062)	13.252*	(0.061)
Alpha	1.083***	(0.000)	0.843***	(0.000)	1.005***	(0.000)
Tau	-0.459**	(0.028)	-0.399**	(0.045)	-0.278	(0.106)
N	882		882		882	

N.B.: P-values in parenthesis: * p<0.1, ** p<0.05, *** p<0.01. In each regression, year dummies are introduced.

2.6 Concluding discussions

Trans-boundary pollution problems are causing intense interregional conflicts in China. In this Chapter, in taking the case of Hebei province, I study whether the border-effect related to trans-boundary pollution exists. Precisely, I study the location decisions of polluting firms in Hebei in estimating whether these firms are more likely to set up in counties close to the provincial border. Estimation results with NBM suggest that the closer a county is to the border, the higher is its probability to attract polluting firms. Thus, there is a risk that people in border counties suffer disproportionately from pollution. Moreover, trans-boundary pollution appears to be a particularly important problem in China because the border-effect has strengthened over time.

If trans-boundary pollution problems are often put forward by opponents of decentralization, the results found in this chapter do not imply that a centralized policy would be optimal. Obviously, a decentralized policy offers compelling advantages in a country as heterogeneous as China. It is unclear which of these two types of policy would lead to higher social welfare. As suggested by Sigman (2005) in the case of the United States, the optimal policy might be to provide targeted solutions to trans-boundary pollution problems while staying within the framework of decentralization. In practice, the EPA of the U.S. has issued the Clean Air Interstate Rule (CAIR) in 2005 to address the National Ambient Air Quality Standards (NAAQS) violation caused by interstate air pollution[53]. Trans-boundary pollution concerns have also given rise to a range of regional environmental conventions in Europe, e.g., the Protocol to the Convention on Long-range Trans-boundary Air Pollution on the Financing of the Co-operative Program for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) was entered into force in 1988[54]. In China, the recent creation of the six regional offices of the MEP could be a way to reduce these perverse effects. However, for the moment, the creation of these offices is too recent and their power is still too limited to offer any measurable effects. It would be interesting to study the location choices of firms in the period to come to test for whether the creation of these intermediate poles between central government and regional governments can be a solution to the trans-boundary pollution problems.

In addition, it would also be interesting to analyze other aspects unsolved in this study. For example, one could test for whether trans-boundary pollution problems are due to a free-riding phenomenon and/or to a pollution haven phenomenon. One could also make a more detailed analysis of firms' location choices according to their

[53] However, this rule has gotten numerous critiques, and has been considered as wholly ineffective, as discussed in Sangi (2011).

[54] Thirty-four ECE countries and the European Community are currently Parties to this Protocol. It is an instrument for international cost-sharing of a monitoring program which forms the backbone for review and assessment of relevant air pollution in Europe in the light of agreements on emission reduction. EMEP has three main components: collection of emission data for SO2, NOx, VOCs and other air pollutants; measurement of air and precipitation quality; and modeling of atmospheric dispersion. At present, about 100 monitoring stations in 24 ECE countries participate in the program. http://www.unece.org/env/lrtap/emep_h1.html.

characteristics, such as type of pollutant discharged or the ownership regime.

Although very interesting, the results obtained in this chapter should be interpreted with caution. It is notable that the model with random effects which is used in panel analysis of this study doesn't allow controlling for the potential correlation between fixed effects and the variables of interest. As a result, the attractiveness of the border counties could come from other elements than (intra-and inter-provincial) environmental regulations differences. On one hand, at borders, one can encounter discontinuities not only in environmental regulations but also in other regulations, e.g. labor regulation.[55] On the other hand, as suggested by Holmes (1998), borders sometimes also reflect geographical discontinuities. For example, it is not unusual for a mountain range or a river to mark the border between two regions or countries. In the case of Hebei, only the border with Shandong seems to be partly "natural": the Canal Wei (Weiyunhe) and the New River of Zhangwei (Zhangweixinhe) mark a part of the border between these two provinces. In this case, it is possible that industrial firms would locate in the border counties along the river to benefit from access to cheap water resource or convenient discharge. It would be interesting to conduct robustness tests of the border-effect in taking into account other types of discontinuity. A potential solution is to conduct the same location choice analysis for all firms without distinguishing polluting ones from the others. If the border-effect was due to other types of discontinuity, all firms and not only the most polluting ones would be attracted to border counties. Unfortunately, the creation data of all firms in Hebei are not available to conduct such a test. Finally, the FDIs count only a very small proportion of the listed firms. As a result, the behavior of foreign companies is not studied separately in this chapter.

[55] For example, Holmes (1998) distinguishes in the U.S. "Pro-business" states, which have an accommodative legislation concerning labor law, from "anti-business" states. In his case, crossing a border would mean escaping from a labor regulation which is not conductive to economic activity. This situation may also exist among Chinese provinces.

Appendix 2.1: Definition of Variables

Variable	Definition	Unit
Creation of firms	Number of creations of polluting firms between 2002 and 2008	Creation
Agglomeration in industry	Number of employed persons in industry per km^2	Persons per km^2
Agglomeration in services	Number of employed persons in services per km^2	Persons per km^2
Wage	Average real wage in industry (2002 price)	Yuan
Population density	Population per km^2	Persons per km^2
Education	Part of secondary students in the total population	%
Local market	Total population	Person
External market	Population of neighbor cities weighted by distance between the county and the cities	
SEZ	Number of Special Economic Zones	SEZ
Border_1	Dummy equal to 1 if the county shares a border with the sea or another province, 0 if not	
Border_2	Length of the common border (with another province or the sea) divided by the total length of the county's boundary	%
Distance	Distance between the county seat and the closest provincial border (with another province or the sea)	Meters
GRP per capita	Real GRP per capita (2002 price)	Yuan
County	Dummy equal to 1 if county, 0 if not	
County city	Dummy equal to 1 if city at county level, 0 if not	

Appendix 2.2: Descriptive Statistics

	Observation	Mean	Standard Deviation	Minimum	Maximum
Creation of firms	147	4.57	10.08	0.00	56.00
Agglomeration in industry	147	29.19	94.58	0.15	573.37
Agglomeration in service	147	38.17	97.94	1.47	643.30
Wage	147	11634.60	2174.87	6903.57	20822.44
Population density	147	683.23	798.49	43.87	5212.67
Education	147	7.11	1.42	3.38	11.99
Local market	147	467946.40	324134.60	113000.00	2991172.00
External market	147	63.60	25.22	0.00	132.51
SEZ	147	0.30	0.62	0.00	4.86
Border_1	147	0.45	0.50	0.00	1.00
Border_2	147	14.36	20.59	0.00	74.28
Distance	147	40631.43	25710.47	354.40	110647.60
GRP per capita	147	12210.33	7337.96	3775.31	37620.39
County	147	0.78	0.42	0	1
County-level city	147	0.15	0.36	0	1

Appendix 2.3: Poisson regression results (Cross-section estimates)

	Border_1	Border_2	Distance
Border_1	0.570*		
	(0.059)		
Border_2		2.519***	
		(0.003)	
Distance			-0.331**
			(0.033)
Agglo. industry	-0.322	-0.341	-0.367
	(0.262)	(0.223)	(0.198)
Agglo. service	2.271**	1.986**	2.273***
	(0.011)	(0.015)	(0.008)
Population density	-2.155***	-1.931**	-2.314***
	(0.005)	(0.010)	(0.002)
Wage	-3.210***	-3.241***	-3.406***
	(0.009)	(0.007)	(0.007)
Education	-0.659	-0.431	-0.471
	(0.395)	(0.551)	(0.533)
Local market	1.502***	1.533***	1.599***
	(0.004)	(0.003)	(0.002)
External market	-0.556***	-0.507***	-0.529***
	(0.000)	(0.000)	(0.000)
SEZ	0.128	0.0545	0.113
	(0.564)	(0.800)	(0.622)
County	1.977	1.346	1.637
	(0.141)	(0.270)	(0.187)
County level city	1.966	1.331	1.656
	(0.134)	(0.256)	(0.173)
GRP per cap.	0.938**	1.007**	1.025**
	(0.028)	(0.019)	(0.013)
Sq. GRP per cap	-0.0917	-0.107	-0.117
	(0.811)	(0.771)	(0.760)
Constant	31.25***	31.80***	38.15***
	(0.007)	(0.004)	(0.002)
Alpha	0.194	0.119	0.179
	(0.260)	(0.495)	(0.299)
Goodness-of-fit test (Prob > chi2)	(0.000)	(0.000)	(0.000)
N	147	147	147

Note: Heteroscedastic-consistent P-values in parenthesis: * p<0.1, ** p<0.05, *** p<0.01.

Appendix 2.4: Evolution of border effects over time (complete table)

	(10)	(11)	(12)	(13)	(14)	(15)
	with contemporaneous variables			with lagged explanatory variables		
	Border_1	Border_2	Distance	Border_1	Border_2	Distance
Agglo. industry	0.127	0.107	0.144	0.149	0.118	0.139
	(0.323)	(0.401)	(0.270)	(0.287)	(0.389)	(0.326)
Agglo. service	1.249***	1.091**	1.076**	0.411	0.192	0.213
	(0.008)	(0.017)	(0.021)	(0.356)	(0.631)	(0.653)
Population density	-1.296***	-1.174***	-1.351***	-0.484	-0.312	-0.571
	(0.006)	(0.010)	(0.003)	(0.298)	(0.461)	(0.232)
Wage	-0.967*	-1.084**	-0.990*	-1.213**	-1.319**	-1.233**
	-0.067	-0.034	-0.058	-0.038	-0.021	-0.035
Education	0.138	0.384	0.181	-0.14	0.0723	-0.109
	-0.697	-0.288	-0.601	-0.71	-0.85	-0.77
Local market	0.972***	0.968***	1.040***	0.674**	0.653**	0.732**
	-0.002	-0.002	-0.001	-0.038	-0.039	-0.026
External market	-0.576***	-0.566***	-0.574***	-0.570***	-0.535***	-0.546***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SEZ	-0.0864	0.00272	-0.0369	0.16	0.24	0.201
	-0.6	-0.987	-0.824	-0.414	-0.211	-0.312
County	1.762*	1.497	1.559*	1.221	0.809	0.802
	-0.059	-0.108	-0.096	-0.223	-0.405	-0.437
County level city	1.743*	1.534*	1.381	1.361	1.003	0.854
	-0.051	-0.081	-0.117	-0.154	-0.267	-0.377
GRP per cap.	0.160	0.141	0.342	0.243	0.252	0.440
	-0.598	-0.632	-0.244	-0.471	-0.438	-0.188
Sq. GRP per cap	-0.374***	-0.241*	-0.368***	-0.267*	-0.126	-0.243
	-0.008	-0.079	-0.009	-0.094	-0.431	-0.131
Var_interest*2002	0.0473	0.262	0.0196	0.160	0.144	0.332*
	(0.890)	(0.773)	(0.916)	(0.649)	(0.880)	(0.092)
Var_interest*2003	0.168	0.201	0.307	0.852**	2.594***	-0.260
	(0.614)	(0.826)	(0.111)	(0.033)	(0.008)	(0.184)
Var interest*2004	0.838**	2.648***	-0.301	0.294	2.068**	-0.204
	(0.027)	(0.005)	(0.116)	(0.441)	(0.039)	(0.313)
Var_interest*2005	0.324	2.040**	-0.214	1.151***	4.589***	-0.498**
	(0.377)	(0.037)	(0.276)	(0.007)	(0.000)	(0.014)
Var_interest*2006	1.159***	4.490***	-0.501***	1.515***	5.803***	-0.663***
	(0.005)	(0.000)	(0.010)	(0.004)	(0.000)	(0.002)
Var interest*2007	1.491***	5.797***	-0.634***	1.364***	5.309***	-0.550***
	(0.004)	(0.000)	(0.002)	(0.005)	(0.000)	(0.009)
Var interest*2008	1.277***	5.144***	-0.524**			
	(0.008)	(0.000)	(0.011)			
Constant	11.04**	12.80**	11.96**	11.60**	13.25**	9.811*
	-0.033	-0.011	-0.023	-0.043	-0.018	-0.09

(End of Appendix2.4)

a	1.405***	1.603***	1.400***	1.476***	1.699***	1.501***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
b	0.21	0.216	0.187	0.0708	0.0963	0.0135
	-0.305	-0.286	-0.347	-0.743	-0.653	-0.948
N	1029	1029	1029	882	882	882

Note: P-values in parenthesis: * p<0.1, ** p<0.05, *** p<0.01. In each regression, year dummies are introduced.

Chapter 3 Strategic interactions in environmental policymaking: evidence from Chinese provinces*

* This chapter is an adapted version of an article co-authored with Professor Mary-Françoise Renard.

3.1 Introduction

The last chapter is devoted to one of the most cited critics of environmental federalism – free riding problems in presence of trans-boundary pollution. In this chapter, I continue to test for another important critic - strategic interaction in environmental policymaking among jurisdictions in the Chinese context.

Critical to the efficiency of decentralization, strategic interaction among governments is a major focus of theoretical and empirical work in public economics. Brueckner (2003) classifies strategic interaction models into two branches, namely spillover models and resource-flow models. Although these models were initially developed to explain fiscal or public finance policymaking, they are also widely employed in environmental federalism studies. Strategic interaction in environmental policymaking can arise due to several reasons, such as capital-competition, pollution spillovers, and yardstick-competition. According to Fredriksson and Millimet (2002b), fears of a destructive competition and excessive pollution were a significant factor leading to the formation of the EPA in 1968 and the regulatory harmonization policy across the European Union.

Although China doesn't have exactly the same environmental federalism as that of the U.S. or that of the E.U., it consists of an interesting field to conduct strategic interaction researches. First of all, environmental policy implementation system is strongly decentralized in China; Chinese provincial governments have *de facto* power over environmental stringency enforcement.[56] In this context, testing for strategic interaction in environmental policymaking will allow understanding the efficiency of this decentralized system. Then, Chinese provinces are very likely to engage in capital competition. On one hand, as discussed in Chapter 1, the one-sided fiscal decentralization has exercised strong fiscal pressure on provincial governments. In order to increase their revenue resources, they would predictably engage in capital competition. On the other hand, several studies show that after the 1978 reforms, Chinese central government has created a yardstick competition among local officials

[56] Discussed in Chapter 1 and further discussed in Chapter 5.

and evaluates them on the basis of economic performance (Li and Zhou, 2005; Maskin *et al.*, 2000; Qian and Xu, 1993). This economic-performance based competition can also give local governments strong incentives to engage in capital competition at the cost of environment. Moreover, as discussed in General Introduction and Chapter 2, in nowadays China, trans-boundary pollution problems have become highlighted issues and free-riding behaviors do exist.[57] As a result, it seems that strategic interaction due to pollution spillovers may also take place.

Unfortunately, very few studies have investigated strategic interaction in environmental policymaking in China. Moreover, although the models proposed by Brueckner (2003) are based on different assumptions, they conduct to the same reaction function for empirical analysis. As a result, most existing studies on the U.S. states don't have a lot to say about the exact reason behind their strategic interaction evidences, except one interesting tentative (Chupp, 2009). In this chapter, I try to contribute to this part of literature in studying the potential strategic interaction in environmental policymaking among Chinese provinces. More importantly, with different identification strategies, I distinguish different assumptions and test for both capital-competition driven and pollution-spillover driven strategic interactions. First I investigate the question of whether Chinese provinces set strategically their environmental stringency vis-à-vis their competitors for mobile capital. I also examine whether the capital-competition driven strategic interaction follows the asymmetric pattern suggested by the race to the bottom theory, and I furthermore study whether this strategic interaction is conditional on fiscal decentralization. Secondly, in order to capture the pollution-spillover driven strategic interaction, I investigate the question of whether SO2 emissions of receptor provinces are responsive to those of their source provinces. The rest of the chapter is organized as follows: in section 2, a brief literature review is made on theoretical and empirical studies of environmental regulatory strategic interaction. Estimation strategy and identification issues are presented in section 3. In section 4 empirical results are reported. And in the last section I conclude and discuss the empirical evidence found

[57] For example, inter-jurisdictional environmental conflicts in the Huai River Basin and the Tai Lake Basin.

in this chapter.

3.2 Literature review

3.2.1 Different theoretical explanations behind strategic interaction

A large and well established body of researches has studied both theoretically and empirically strategic interaction in fiscal and public finance policymaking among local governments. According to Revelli (2005), local governments can be thought of as interacting with one another along three main channels: preferences, constraints and expectations, which correspond respectively to the spillover, resource-flow and yardstick-competition models discussed in Brueckner (2003). Although these models were originally created to explain fiscal and public finance policymaking, they can be and have been already borrowed by a lot of environmental federalism researches.

The preferences interaction (or spillover) models assume that a local government's policymaking (e.g. public services provision) enters the welfare function of its neighboring jurisdictions and affects directly the preferences of the latter. In the domain of public finance, Case *et al.* (1993), Murdock *et al.* (1993) and Revelli (2003) evaluate the interaction among neighboring jurisdictions' expenditures. In the domain of environmental policymaking, spillover models assume that one jurisdiction's policy making will depend on that of its neighbors due to pollution spillovers, i.e., the pollution suffered by one jurisdiction's population is determined not only by its own emissions but also by those of its neighbors if the pollutant is trans-boundary. Murdoch *et al.* (1997) and Fredriksson and Millimet (2002b) model strategic interaction based on pollution spillovers. The former examine the interaction in adherence behaviors among European countries to sulphur and nitrogen oxide emission reduction protocols; the latter are interested in whether U.S. states incorporate their neighboring states' regulatory stringency (abatement cost) into their own decision making.

Capital-competition models can be classified into the branch of constraints interaction (or resource-flow) models. These models are originally presented by tax competition theory (Oates, 1972). Tax competition theory assumes that jurisdictions compete with each other using tax rates for a fixed amount of mobile resource in order to maximize local welfare (Brueckner and Saavedra, 2001; Buettner, 2001; Wilson, 1986). In the field of environmental regulations, competition can take place among jurisdictions if they compete with each other with environmental stringency to attract a fixed amount of mobile capital. A great number of theoretical studies address this subject and establish the framework to analyze welfare implication of inter-jurisdictional environmental regulatory competition (Dijkstra, 2003; Glazer, 1999; Kunce, 2004; Kunce and Shogren, 2002, 2005, 2007; Levinson, 1997; Markusen *et al.*, 1995; Oates and Schwab, 1988; Roelfsema, 2007; Wellisch, 1995). Particularly, many of them are interested in the “race to the bottom” hypothesis, under which destructive competition leads to excessively weak environmental stringency. In the U.S. context, critics of decentralization often argue that states are primarily concerned with economic development and will relax their environmental regulations in order to gain an advantage over other states (Konisky, 2007).

The expectations interaction (yardstick-competition) models are originally developed to explain incumbents’ behavior in tax setting (Besley and Case, 1995). Yardstick competition arises because imperfectly informed voters in a local jurisdiction use other governments' performance as a yardstick to evaluate their own government. Because yardstick competition models involve information spillovers across jurisdictions, Brueckner (2003) classifies them in the branch of spillover models. In environmental policymaking, yardstick competition can also matter if a local government uses its neighbors’ environmental performance as a benchmark and try not to get too far out of line. For example, Fredriksson and Millimet (2002a) model interstate yardstick competition in setting pollution abatement expenditures in the U.S.

3.2.2 Empirical evidences of environmental regulatory strategic interaction

Numerous studies have found empirical evidences of environmental regulatory strategic interaction. For example, Fredriksson and Millimet (2002b) measure the regulatory stringency by the environmental abatement costs and find that U.S. states do incorporate asymmetrically their neighboring states' regulatory stringency into their own decision making, i.e., a state is incited to apply higher abatement costs if its neighbors with relatively stringent regulations increase theirs. Using two panels of data on states' regulatory stringency, Levinson (2003) examines whether regulatory competition becomes more severe during the Reagan administration, when state control of environmental policy is greater. He finds that "states behave strategically, reacting to other states' environmental standard stringency when setting their own," but he doesn't find convincing evidence that competition steepened during the Reagan administration. Woods (2006) conducts an analysis of state surface-mining regulation to determine if the enforcement gap between a state and its competitors affects the stringency of the former. He finds evidence of a race to the bottom in that states adjust their enforcement in response to their competitors when their enforcement stringency exceeds that of their competitors. Konisky (2007) compiles data on state enforcement of three U.S. federal pollution control programs: the CAA, the CWA, and the RCRA.[58] He constructs two measures of annual state enforcement effort: the annual number of sampling inspections and the unweighted sum of informal and formal punitive actions. Using spatial panels, he finds robust evidence of strategic regulatory behaviors across the U.S. states. However, his evidence does not support the asymmetric pattern of strategic interaction predicted by the race to the bottom theory.

Among the empirical studies mentioned above, several test for strategic interaction by estimating reaction functions[59] with spatial data and estimators.

[58] Abbreviations of three federal pollution control programs: the Clean Air Act (CAA), the Clean Water Act (CWA), and the Resource Conservation and Recovery Act (RCRA).

[59] A reaction function shows how a jurisdiction responds to the choices of neighboring jurisdictions in setting the level of its own decision variable.

Although very interesting, these methods do not allow discriminating among different theoretical explanations behind the observed spatial autocorrelation (Revelli, 2005). Since both the spillover models and the resource-flow models generate similar reduced form inter-jurisdictional reaction functions (Brueckner, 2003), strategic interaction found in this way may be actually a mixed result of different effects.[60] An interesting tentative to overcome this problem is made by Chupp (2009), who tries to distinguish spillover effects from capital-competition effects by adopting two weighting matrix: a state-to-state pollution transport matrix and an industrial similarity matrix. In this chapter, I follow his strategy and try to distinguish different assumptions behind environmental strategic interaction among Chinese provinces.

3.3 Estimation strategy

This section presents the strategy used in the empirical analysis and different issues to be considered in estimation.

3.3.1 Spatial econometric issues

The standard way to test empirically for strategic interaction is to use a spatial-lag econometric model (Brueckner, 2003). This model is typically considered as the formal specification for the equilibrium outcome of a spatial or social interaction process, in which the value of the dependent variable for one agent is jointly determined with that of the neighboring agents (Elhorst, 2010). In a spatial-lag model, the pattern of interaction among jurisdictions is modeled by specifying a particular weighting matrix. The standard spatial-lag panel model can be written in (3.1):

[60] Revelli (2005) proposes three approaches for identifying the structural model generating the observed spatial pattern. The first one is based upon estimation of auxiliary equations that are directly derived from the theory. The second approach explores the role of exogenous policy shocks in a sort of "natural experiment." The third approach exploits the presence of particular institutional arrangements that generate both horizontal and vertical fiscal interactions.

$$Y_{it} = \delta \sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt} + \boldsymbol{\beta X_{kit}} + \mu_i + d_t + \varepsilon_{it}$$

$$|\delta| < 1, \quad i = 1, ..., N, \quad k = 1, ..., K, \quad t = 1, ..., T \qquad (3.1)$$

where index i is for the cross-sectional dimension (provinces in my sample), t is for the time dimension, Y_{it} is the dependent variable, $\mathbf{W_{ijt}}$ is an N^2 ordered spatial weighting matrix describing the importance assigned to jurisdiction j by jurisdiction i at time t, $\sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt}$ is the spatially lagged dependant variable, $\boldsymbol{X_{kit}}$ is an (N,K) vector of independent variables, $\boldsymbol{\beta}$ is a $(K,1)$ vector of fixed but unknown parameters, δ is the spatial autoregressive coefficient, μ_i denotes a spatial specific effect which controls for all space-specific time-invariant variables whose omission could bias the estimates in a typical cross-sectional study, d_t is a time specific effect which controls for all unobservable time-specific space-invariant omitted variables, and ε_{it} is an independently and identically distributed error term with zero mean and variance σ^2.

In (3.1), $\sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt}$ is endogenous because of simultaneous causality with regard to Y_{it}. In order to address this problem, two estimators have been developed. One is a maximum likelihood (ML) estimator proposed by Anselin (1988), and the other is a two-stage least squared instrumental variable (2SLS-IV) estimator proposed by Kelejian and Prucha (1998). According to Anselin (1988), spatial autocorrelation across data can emerge in two ways: first, spatial-lag autocorrelation emerges when Y_{it} and $\sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt}$ are simultaneously determined by each other; secondly spatial-error autocorrelation emerges if error terms are spatially auto-correlated with each other. Before using the ML estimator, a choice between spatial-lag and spatial-error models must be made, otherwise estimation of (3.1) would provide false evidence of strategic interaction (Brueckner, 2003). For this purpose, Anselin *et al.*

(1996) propose the Lagrange Multiplier (LM) test and its robust version. However, the LM test as well as the ML estimator requires a normal distribution of error terms, otherwise test statistics would be biased (Elhorst, 2010).

Unfortunately, in the present study, condition of normally distributed errors can't be satisfied.[61] That's why I turn to the alternative 2SLS-IV model. The 2SLS-IV approach has been used in numerous strategic government interaction studies (Figlio *et al.*, 1999; Fredriksson and Millimet, 2002b; Levinson, 2003). This IV method has the virtue of not depending on normal distribution hypothesis. Moreover, Kelejian and Prucha (1998) show that their method generates a consistent estimate even in the presence of spatial-error dependence. The standard application of the 2SLS-IV approach is to instrument for Y_{jt} with a subset of the weighted characteristics of neighbors: $\sum_{j \neq i} \mathbf{W_{ijt}} \boldsymbol{X_{kjt}}$. The first stage of the 2SLS takes the form of (3.2):

$$\sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt} = a + \boldsymbol{b} \sum_{j \neq i} \mathbf{W_{ijt}} \boldsymbol{X_{sjt}} + \eta_{it}, \quad i = 1, \dots, N, \quad s = 1, \dots, S, \quad t = 1, \dots, T \qquad (3.2)$$

where $\sum_{j \neq i} \mathbf{W_{ijt}} \boldsymbol{X_{sjt}}$ is a subset of weighted average of competitors' characteristics $\sum_{j \neq i} \mathbf{W_{ijt}} \boldsymbol{X_{kjt}}$, which satisfies the instrument exclusion restrictions.

3.3.2 Identification issues

Two major issues arise when one tries to identify potential strategic interaction among jurisdictions. One is to identify neighbors against non-neighbors; the other is to assign appropriate relative importance to each designated neighbor. Both of these issues have to be addressed in constructing weighting matrices which reflect interaction patters among jurisdictions.

First, it is reasonable to assume that the decision making of a Chinese province may be affected by only a certain number of other provinces (defined as its neighbors), and not by all other provinces. In the literature, different neighbor definitions have

61 Jacque-Bera statistics reported in Table 3.1.

been adopted. The simplest and commonly used one is a geographical contiguous definition. This definition assumes that jurisdictions interact with each other if they share common borders. The corresponding weighting matrix for contiguous neighbors is a contiguity matrix.[62] A second way to define neighbors is based on geographical distance: jurisdictions are considered as neighbors if the geographical distance between them is inferior to a certain critical value. A third way to identify neighbors is based on similarity criteria. This definition assumes that jurisdictions interact with each other not because they share the same border but because they share a set of similarities, e.g. the same region, similar industrial structure, similar income level, similar racial composition, etc. In the U.S. context, two regional classifications are frequently used, namely the BEA (Bureau of Economic Analysis) classification and the classification proposed by Crone (1998/1999). Finally, a fourth way to identify neighbors is based on trans-boundary pollution transfers matrix. This method is particularly interesting for spillover-model estimation. Since the 1980s', meteorological and geographical data have been used to model air pollution transfer scenarios in the U.S. and in Europe.[63] Interesting products of these models are source-receptor matrices, which have been used to analyze strategic interactions among the U.S. states (Chupp, 2009) or among European countries (Mäler and De Zeeuw, 1998; Murdoch *et al.*, 2003)

Secondly, it is also important to assign relative importance to different neighbors. Implicit in the choice of weights is the assumption that states may be more responsive to environmental policy in neighboring states responsible for greater generation of trans-boundary pollution or greater competition for capital. Different weighting schemes have been adopted in the literature. For example, Fredriksson *et al.* (2004) and Fredriksson and Millimet (2002b) each use three different schemes, namely equal weights, population weights, and income weights. Konisky (2007) uses population weights and argues that results are not sensitive to weighting choice. In a distance

[62] In a contiguity matrix, "one" is given to two cities sharing common border and "zero" in the opposite case.

[63] The Ambient Source Trajectory Regional Air Pollution (ASTRAP) model in the Tracking and Analysis Framework (TAF) in the U.S. (Bloyd *et al.*, 1996) and the Regional Acidification Information Simulation (RAINS) model developed for the EMEP in Europe (Eliassen and Saltbones, 1983; Sandnes, 1993)

matrix, neighbors are weighted by the inverse of geographical distance (Madariaga and Poncet, 2007). In an income similarity matrix, neighbors are weighted by the inverse of absolute value of income per capita difference (Case *et al.*, 1993). In a source-receptor matrix, neighbors are weighted according to air pollution transfers degree, i.e., each receptor jurisdiction assigns a weight to a source neighbor based on the percentage of its damages caused by that source neighbor (Chupp, 2009).

Identification of interaction pattern is an important issue. As argued in Revelli (2005), although spatial econometric methods allow testing for existence of strategic interaction, they do not allow discriminating among different theoretical explanations behind the observed spatial autocorrelation. In this chapter, I try to distinguish capital-competition driven and pollution-spillover driven strategic interaction among Chinese provinces. For this purpose, different weighting matrices are adopted. First of all, classical contiguity matrices with equal, population and income weights are used to test for the overall effect. It is notable that strategic interaction found in assuming these geographically based patterns may be a mix of different effects (e.g. pollution spillovers and capital competition.) As a result, in order to test more specifically for capital-competition driven interaction, an industrial structure similarity matrix ($\mathbf{W}_{\mathrm{Iijt}}$) is constructed with annual sectorial data of each province. This matrix weights a province's neighbor by an index of industrial structure similarity between them.[64] The implicit assumption is that competition for capital is more likely to take place between provinces with similar industrial structures (Chupp, 2009). Meanwhile, in order to test for the strategic interaction driven by pollution spillover effects, a province-to-province SO2 transport matrix ($\mathbf{W}_{\mathrm{Sij}}$) in terms of sulfur deposition has been constructed with data compiled from the RAINS-ASIA model. $\mathbf{W}_{Sij}$ allows calculating, for each downwind receptor province, the weighted average SO2 emission of its upwind provinces. Since the spatial relative distribution of emissions is constructed with 1990-1995 meteorological data, it is invariant over time and

[64] Different indices have been proposed in the literature to estimate structure similarity between economies (Brixiova *et al.*, 2010; Krugman, 1991; Landesmann and Szekely, 1995; UNIDO, 1979). In this paper, the index proposed by UNIDO (1979) is used. More details on the construction of this index can be found in Appendix 3.1.

considered exogenous to the strategic interaction model[65].

3.3.3 Some issues to be considered in capital-competition model

3.3.3.1 Asymmetric effects model

A specific asymmetric pattern is suggested by the race to the bottom theory, according to which a province responds to its competitors only if its own regulatory situation is at a disadvantage vis-à-vis its competitors.[66] Following Fredriksson and Millimet (2002b) and Konisky (2007), I consider an alternative model where provinces' responsiveness is asymmetric:

$$Y_{it} = \delta_0 I_{it} \sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt} + \delta_1 (1 - I_{it}) \sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt} + \boldsymbol{\beta X_{kit}} + \mu_i + d_t + \varepsilon_{it}$$

$$i = 1, ..., N, \quad k = 1, ..., K, \quad t = 1, ..., T \qquad (3.3)$$

where

$$\begin{cases} I_{it} = 1, \text{ if } \ Y_{it} > \sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt}; \\ I_{it} = 0, \text{ otherwise.} \end{cases}$$

In (3.3), I_{it} = 1 if province i's own environmental stringency is above that of its competitors, i.e., i is at a disadvantage for attracting mobile capital relative to its competitors. On the contrary, I_{it} = 0 if province i's own environmental stringency is below that of its competitors, i.e., i is at an advantage for attracting mobile capital relative to its competitors. The race to the bottom theory suggests that $\delta_0 > 0$, and that δ_1 should not be statistically different from zero.

[65] More details on RAINS-ASIA model and construction of province-to-province source-receptor matrix can be found in Appendix 3.2.

[66] The race to the bottom theory suggests also another asymmetric pattern: a jurisdiction responds only if the weighted average of its competitors' environmental enforcement efforts drop from the previous year (Konisky, 2007). We haven't tested for this model because quasi total observations in the present sample have decreasing pollution levy over the period 2004-2009.

3.3.3.2 Nonlinear effects model

It is possible that strategic interaction among provinces is not linear and is conditional on certain provincial characteristics, e.g. fiscal arrangements. As discussed in Chapter 1, under China's one-sided fiscal decentralization, sub-national governments suffer from significant fiscal imbalance and have excessively heavy expenditure responsibilities which are mismatched with their revenue assignments. Environment can thus be victim of this situation: given the severe budgetary pressures, local governments may use lax environmental stringency as a tool for attracting mobile capital and creating taxable resources. If this is the case, fiscal imbalance will strengthen capital-competition driven strategic interaction. Moreover, fiscal imbalance is distributed in an unequal way. As a result, it is reasonable to assume that provinces with greater fiscal imbalance would be likely to react more strategically when enforcing their environmental regulations. In order to control for this nonlinear effect, I introduce an interaction term $\mathbf{W_{ijt}}Y_{jt} * IMB_{it}$, where IMB_{it} is an indicator of fiscal imbalance of province i in year t. The nonlinear effects model to estimate is specified in (3.4):

$$Y_{it} = \delta \sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt} + \varphi \; IMB_{it} * \sum_{j \neq i} \mathbf{W_{ijt}} Y_{jt} + \pi \; IMB_{it} + \boldsymbol{\beta X_{kit}} + \mu_i + d_t + \varepsilon_{it}$$

$$i = 1, ..., N, \quad k = 1, ..., K, \quad t = 1, ..., T \qquad (3.4)$$

3.4 Empirical analysis of interprovincial strategic interactions

3.4.1 Data and variables

The present study uses a panel dataset of 30 Chinese provinces (Tibet, Hongkong and

Macao excluded) over the period of 2004-2009. The main sources of data are China Statistical Yearbook (2005-2010), China Environment Yearbook (2005-2010) and China Industrial Economic Statistical Yearbook (2005-2010). 2004 is chosen as the beginning year of the study because it is the year when China Industrial Economic Statistical Yearbook starts to publish consistent data of sectorial added values by province. Before that year, data of several sectors, e.g. textile garments, shoes and caps products, and special equipment manufacturing industry, were not reported. Since consistent sectorial data are indispensible to construct the industrial similarity weighting matrix, I decide to conduct the empirical analysis on the period post-2004.

The dependent variable (*Y*) of the capital-competition model is provincial pollution levy per industrial added value. This indicator is used as a proxy of environmental stringency. Provincial levy per industrial added value can be a proxy of the environmental stringency for several reasons: first, In China, concentration standards for levy collection are set jointly at the national and provincial levels thus vary across provinces and reflect provincial enforcement level (Dean *et al.*, 2009). Secondly, pollution levy is an economic regulatory instrument implemented at local level. Several studies show that levy affects significantly polluters' behaviors (Dasgupta *et al.*, 2001; Wang and Wheeler, 2003). As a result, one may expect that levy matters for attracting polluting capital. Finally, different from other studies which use levy per volume of pollution (e.g., Dean *et al.* (2009)), this study uses levy per industrial added value because only aggregated levy data (without details by pollutant) have been reported during the period 2004-2009. As a result, levy per industrial added value is a proxy of the overall environmental stringency.

In order to test for nonlinear effects, provincial fiscal imbalance (*IMB*) is introduced in equation (3.4). *IMB* is a vertical imbalance indicator defined by (3.5):

$$IMB_{it} = \frac{Transfers_{it}}{Expenditures_{it}}, \qquad t = 1,...,T,\ i = 1,...,I \tag{3.5}$$

where i denotes the province, t denotes the year, $Transfers_{it}$ denotes the total fiscal transfers that province i receives from the central government in year t, and

$Expenditures_{it}$ denotes the consolidated budgetary expenditures spent by province i in year t. The construction of *IMB* is inspired by IMF's Government Finance Statistics (GFS), where vertical imbalance of a country is measured by transfers to sub-national governments as a share of sub-national government expenditures. In this chapter, *IMB* measures the degree to which province i relies on transfers from central government to fulfill its expenditure responsibilities.[67]

Other independent variables are introduced to control for provincial characteristics. First of all, one may argue that levy per industrial added value of a province is not only determined by its environmental stringency but also by the pollution intensity of its industrial production. It is true that a province with weak environmental standards may collect high levy per industrial added value if more pollution is associated with each unit of its industrial production. In order to control for this endogeneity, I introduce intensities of two major industrial pollutants– sulfur dioxide and chemical oxygen demand per industrial added value (*SO2intensity* and *CODintensity*). Then, in following the EKC hypothesis, I include gross regional product per capita (*GRP*) as a proxy of income per capita, its squared term (GRP^2) and its cubed term (GRP^3). Income per capita reflects economic development level of a province and is considered to affect the environmental performance through scale, composition and technique effects (Brock and Taylor, 2005). After that, population density (*Density*) is also included. Population density can affect environmental performance through scale effects. Governments may also make more efforts to abate pollution where it's more densely populated. In addition, Wang *et al.* (2003) show that state-owned enterprises have more bargaining power with local environmental authorities when negotiating the enforcement of pollution levy. As a result, I suppose that the importance of state-owned sector in a province's industry may have an effect on its environmental stringency. To capture this effect, the proportion of industrial added value realized by state-owned enterprises (*State*) is introduced. Moreover, two openness variables – trade opening (*Trade*) and FDI (*FDI*) are also included. Trade

[67] Following the GFS indicator, *IMB* doesn't distinguish conditional transfers versus general purpose transfers, due to data unavailability.

opening may affect a province's industrial structure and furthermore affect its environmental stringency though the "composition" effect[68] (Cole and Elliott, 2003). FDI is introduced because environmental levy enforcement is shown to have effect on FDI localization among provinces (Dean *et al.*, 2009; He, 2006). Provinces with different levels of FDI may have different incentives to attract foreign capital with pollution levy. Furthermore, public pressure can also affect the enforcement of environmental levy (Wang and Di, 2002; Wang and Wheeler, 2003). Two variables are introduced to control for this effect: citizen complaint letters regarding environmental issues (*Letters*) and percentage of population with high-education (*Edu*). Finally, provincial specific effects and year dummies are introduced to control for non-observed provincial or time specific effects. Variable definitions and descriptive statistics are reported in Appendix 3.3 and 3.4.

Unfortunately, pollution levy is not an ideal dependent variable for spillover-effect model. In effect, the source-receptor matrix used for this purpose considers only one pollutant - SO2 (and not other pollutants) - transfers among provinces, while the levy data are aggregated. Default of a direct measure of environmental stringency regarding SO2 emission, SO_2 emission per capita (*SO2*) is chosen as dependent variable to test for the spillover-effect model. In other words, I examine whether the SO2 emission behavior in sources provinces affect that in receptor provinces. Although SO2 emission per capita is not a direct regulation measure, there is little doubt that it is the result of environmental policy. In the spillover-effect model, all control variables presented above are included except the two pollution intensities (*SO2* and *COD*).

3.4.2 Estimation Results

3.4.2.1 Results for capital-competition driven strategic interaction

In order to test for capital-competition driven strategic interaction, estimations are

[68] The "composition" effect refers to the way that trade liberalization changes the mix of a country's production towards those products where it has a comparative advantage.

made first using classical contiguity matrices with different weighting schedules, and then using industrial structure similarity matrix with linear, asymmetric and nonlinear effects.

3.4.2.1.1 Results with contiguity matrices

Table 3.1 presents estimation results of equation (3.1) with contiguity matrices. Equal weights, population weights, and income weights are used respectively. Jacque-Bera test statistics show strongly abnormal residuals, which leads to a preference for IV estimator to ML estimator. Hausman test statistics allow rejecting its null hypothesis in none of the specifications. So efficient models with random effects are preferred and adopted. Column 1 presents results with equally weighting contiguity matrix. Column 2 presents results with population weighting contiguity matrix, and column 3 with income weighting contiguity matrix. A subset of $\mathbf{W_{ijt}}\boldsymbol{X_{kjt}}$ is used as instruments in all regressions.[69] Kleibergen-Paap rk LM statistics indicate that the null hypothesis of under-identified instruments can be rejected for all 2SLS regressions; the null hypothesis of exogenous $\sum_{j\neq i}\mathbf{W_{ijt}}Y_{ijt}$ is strongly rejected for equal and income weights and cannot be rejected at 5% level for population weights; Hansen statistics show that the null hypothesis of orthogonal instruments cannot be rejected at the confidence level of 5%.

Results show that for equal and income weights, everything else being equal, geographical contiguous provinces do interact strategically with each other and in the same direction in setting their environmental enforcement stringency. However, the strategic interaction found in these two cases is weak in level (with elasticity inferior to 0.1) and in significance (the null hypothesis of zero strategic interaction cannot be rejected at the confidence level of 5 %.) Regarding population weights, the absence of strategic interaction cannot be rejected at 10% level. These results suggest that strategic interaction among contiguous provinces is weak and positive, if there is any.

[69] Note that the contiguity matrix with equal weights is not time-variant.

Nevertheless, one should be skeptical facing these results because as stated previously, contiguity is a very simplified interaction pattern: on one hand, provinces may interact with each other even if they don't share common borders; on the other hand, given different theoretical explanations behind strategic interaction, the weak evidence may simply be due to a mix of different driving effects.

Table 3.1: Results of (3.1) with different weighting contiguity matrices

Y=Levy	Equally weighting contiguity matrix		Population weighting contiguity matrix		Income weighting contiguity matrix	
$\sum \mathbf{W}_{\mathbf{ijt}} Y_{ijt}$	0.069*	(0.056)	0.079	(0.131))	0.090*	(0.057))
GRP3	-0.231***	(0.001)	-0.233***	(0.001)	-0.223***	(0.001)
GRP2	5.357***	(0.001)	5.406***	(0.001)	5.165***	(0.001)
GRP	-40.845***	(0.001)	-41.160***	(0.001)	-39.405***	(0.001)
SO2intensity	0.562***	(0.000)	0.565***	(0.000)	0.583***	(0.000)
CODintensity	0.070	(0.543)	0.071	(0.564)	0.064	(0.589)
Density	0.144**	(0.045)	0.161**	(0.021)	0.162**	(0.015)
State	-0.179	(0.606)	0.415	(0.562)	0.527	(0.453)
Trade	-0.327	(0.214)	-0.323	(0.241)	-0.307	(0.244)
FDI	-3.323	(0.110)	-3.485	(0.108)	-3.271	(0.117)
Letters	-0.085***	(0.001)	-0.084***	(0.002)	-0.082***	(0.002)
Edu	-0.367	(0.838)	-0.155	(0.932)	-0.184	(0.916)
Dum2005	0.081	(0.210)	0.076	(0.270)	0.075	(0.272)
Dum2006	0.076	(0.293)	0.069	(0.356)	0.072	(0.328)
Dum2007	-0.045	(0.671)	-0.042	(0.710)	-0.030	(0.781)
Dum2008	0.045	(0.777)	0.056	(0.746)	0.072	(0.664)
Dum2009	-0.037	(0.853)	-0.013	(0.954)	0.010	(0.964)
Constant	97.672***	(0.003)	98.082***	(0.002)	93.876***	(0.003)
Number of obs	180		180		180	
Number of groups	6		6		6	
Centered R2	0.520		0.511		0.521	
Uncentered R2	0.986		0.985		0.987	
Jacque-Bera test Prob>chi2			(0.000)			
Hausman test Prob>chi2	(0.645)		(0.612)		(0.940)	
Kleibergen-Paap rk LM statistic Prob>chi2	(0.000)		(0.000)		(0.005)	
Anderson-Rubin Wald test Prob>chi2	(0.021)		(0.154)		(0.005)	
Hansen J statistic Prob>chi2	(0.146)		(0.458)		(0.225)	

Note: Heteroscedastic-consistent *p-value* in parentheses, with ***, ** and * denoting significance at 1, 5 and 10 percent level, respectively

3.4.2.1.2 Strategic interaction with industrial structure similarity matrix

Estimation results with industrial structure similarity matrix are presented in Table 3.2. The first column reports results for linear strategic interaction specified in equation (3.1); the second column reports results for asymmetric strategic interaction specified in equation (3.3); and the third column reports results for nonlinear strategic interaction specified in equation (3.4). For all 2SLS regressions, models with random effects are preferred. Test statistics show that the null hypothesis of under-identified instruments and the null hypothesis of the absence of endogeneity are rejected at 5%; the null hypothesis of over-identified instruments cannot be rejected at 5%.

Results suggest that strategic interaction among provinces with similar industrial structure is much stronger and more significant than what was found among contiguous neighbors. When linear effect is considered, estimation results of equation (3.1) show that, *ceteris paribus*, a province would decrease (increase) its own environmental levy per industrial added value by 1.947% if its weighted competitors decrease (increase) theirs by 1%. The null hypothesis of zero strategic interaction can be rejected at the confidence level of 5%. These results indicate that environmental regulation stringencies of industrial competitors are effectively strategically determined.

When equation (3.3) is estimated, results reported in the second column don't show evidence of asymmetric responsiveness. According to the race to the bottom theory, only the coefficient of $I_{it}\sum_{j \neq i}\mathbf{W_{ijt}}Y_{jt}$ should be positive and significant. However, we find that the coefficients of $I_{it}\sum_{j \neq i}\mathbf{W_{ijt}}Y_{jt}$ and $(1-I_{it})\sum_{j \neq i}\mathbf{W_{ijt}}Y_{jt}$ are both positive and weakly significant. This finding suggests that, no matter whether a province's environmental stringency is stricter or not than its competitors, strategic interaction is not asymmetrically differential as predicted by the race to the bottom theory.[70]

Table 3.2: Strategic interaction with industrial structure similarity matrix

Y=Levy	Results of (3.1)		Results of (3.3)		Results of (3.4)	
$IMB_{it} * \sum \mathbf{W_{ijt}} Y_{ijt}$					2.106**	(0.032)
$I_{it} \sum \mathbf{W_{ijt}} Y_{ijt}$			1.461*	(0.071)		
$(1-I_{it}) \sum \mathbf{W_{ijt}} Y_{ijt}$			1.519*	(0.061)		
$\sum \mathbf{W_{ijt}} Y_{ijt}$	1.947**	(0.050)			1.869**	(0.049)
GRP3	-0.240***	(0.002)	-0.221***	(0.003)	-0.310***	(0.000)
GRP2	5.664***	(0.001)	5.168***	(0.003)	7.151***	(0.000)
GRP	-44.020***	(0.001)	-39.891***	(0.002)	-54.721***	(0.000)
SO2intensity	0.438***	(0.001)	0.398***	(0.000)	0.449***	(0.000)
CODintensity	0.141	(0.230)	0.100	(0.273)	0.151	(0.178)
Density	0.144*	(0.057)	0.153***	(0.007)	0.128*	(0.094)
State	-0.509	(0.226)	-0.191	(0.580)	-0.543	(0.214)
Trade	-0.211	(0.486)	-0.145	(0.584)	-0.099	(0.739)
FDI	-2.668	(0.189)	-2.472	(0.146)	-2.290	(0.265)
Letters	-0.094***	(0.000)	-0.073***	(0.002)	-0.097***	(0.000)
Edu	-0.028	(0.988)	-0.149	(0.922)	1.136	(0.567)
IMB					13.143**	(0.042)
Dum2005	-0.041	(0.688)	-0.042	(0.638)	-0.123	(0.287)
Dum2006	0.049	(0.547)	0.012	(0.875)	0.031	(0.706)
Dum2007	0.044	(0.712)	-0.037	(0.710)	0.131	(0.265)
Dum2008	0.554*	(0.067)	0.323	(0.202)	0.931***	(0.005)
Dum2009	0.676	(0.102)	0.390	(0.270)	1.231***	(0.008)
Constant	120.567***	(0.000)	105.775***	(0.001)	146.316***	(0.000)
Number of obs	180		180		180	
Number of groups	6		6		6	
Centered R2	0.472		0.636		0.463	
Uncentered R2	0.985		0.993		0.988	
Hausman test Prob>chi2	(0.338)		(0.076)		(0.783)	
Kleibergen-Paap rk LM statistic Prob>chi2	(0.000)		(0.000)		(0.000)	
Anderson-Rubin Wald test Prob>chi2	(0.013)		(0.000)		(0.037)	
Hansen J statistic Prob>chi2	(0.110)		(0.056)		(0.216)	

Note: Heteroscedastic-consistent *p-value* in parentheses, with ***, ** and * denoting respectively significance at 1, 5 and 10 percent level

[70] In the U.S. context, Fredriksson and Millimet (2002b) and Konisky (2007) haven't found asymmetric effects suggested by the race to bottom theory neither.

Finally, estimation results of the nonlinear effects model (3.4) are reported in the last column. Consistent with the prediction in section 3, the interaction term $\mathbf{W_{ijt}} Y_{jt} * IMB_{it}$ has a positive and significant coefficient of 2.106, which suggests that strategic interaction among provinces is conditional on provincial fiscal imbalance. The more a province is fiscally dependent on central government's transfers for expenditures, the more strategically it will set its environmental stringency vis-à-vis its competitors. These results are helpful to understand the potential inefficiency of China's actual fiscal decentralization system for public good provision, especially in the environmental protection domain. Marginal effects of competitors' environmental stringency conditional on fiscal imbalance are presented in Appendix 3.4. Over the period 2004-2009, the province which has the strongest strategic interaction would be Qinghai, with a mean marginal effect of 3.688; the province which has the weakest strategic interaction would be Beijing, with a mean marginal effect of 2.233. In other words, *ceteris paribus*, a decrease (an increase) of 1% in environmental stringency of their competitors would induce Qinghai and Beijing to decrease (increase) their own environmental stringency by 3.688% and 2.233%, respectively.

Concerning control variables, GRP per capita, its squared and cubed terms have significant coefficients in all regressions. Population density has always a positive and significant coefficient, suggesting that everything else being equal, environmental stringency is stricter where it is more populated. In addition, complaint letter number has always a negative and significant coefficient, suggesting that public pressure weakens environmental stringency. This seems against intuition but is not surprising: public pressure of a province and its environmental stringency are high likely to be simultaneously affected. It is normal that stricter environmental stringency leads to fewer complaints. Since complaint letter number is only a control variable, its endogeneity is not addressed in this chapter.

3.4.2.2 Results for pollution-spillover driven strategic interaction

Table 3.3 presents estimation results of equation (3.1) with SO2 per capita emission and different contiguity matrices. A subset of $\mathbf{W_{ijt}}\boldsymbol{X_{kjt}}$ is used as instruments in all regressions. Hausman test statistics allow a preference for models with random effects; Kleibergen-Paap rk LM statistics indicate that the null hypothesis of under-identified instruments can be rejected in all 2SLS regressions; the null hypothesis of exogenous $\sum_{j\neq i}\mathbf{W_{ijt}}Y_{ijt}$ is strongly rejected for equal weights and cannot be rejected at 5% level for income and population weights; Hansen statistics show that the null hypothesis that the instruments satisfy the orthogonality conditions cannot be rejected at the confidence level of 5%.

Consistent with results when pollution levy is independent variable, geographically contiguous provinces do interact strategically with each other and in the same direction in discharging SO2 pollution, with elasticities around 0.33. Moreover, these interactions are very significant (the null hypothesis of zero strategic interaction cannot be rejected at the confidence level of 1 %). Nevertheless, as stated previously, contiguity is a very simplified interaction pattern and these positive interactions may simply be due to a mix of different driving effects. As a result, in order to test more specifically for the pollution-spillover model, the SO2 transport matrix reflecting source-receptor relations is used in the following analysis.

Table 3.3: Results of (3.1) with different weighting contiguity matrices

Y=SO2 per capita	Equally weighting contiguity matrix		Population weighting contiguity matrix		Income weighting contiguity matrix	
$\sum \mathbf{W}_{\mathbf{Cijt}} Y_{ijt}$	0.336***	(0.000)	0.347***	(0.000)	0.322***	(0.000)
GRP3	-0.074***	(0.000)	-0.076***	(0.000)	-0.069***	(0.002)
GRP2	1.659***	(0.000)	1.680***	(0.001)	1.538***	(0.003)
GRP	-12.256***	(0.000)	-12.279***	(0.001)	-11.294***	(0.003)
Density	-0.033	(0.781)	-0.068	(0.586)	-0.060	(0.627)
State	1.552*	(0.051)	-0.146	(0.292)	-0.193	(0.167)
Trade	-0.279*	(0.055)	-0.307**	(0.030)	-0.306**	(0.034)
FDI	-0.637	(0.561)	-0.963	(0.397)	-1.100	(0.353)
Letters	0.003	(0.667)	0.002	(0.721)	0.003	(0.627)
Edu	0.755	(0.397)	0.876	(0.329)	0.753	(0.395)
Dum2005	0.102***	(0.003)	0.093***	(0.004)	0.094***	(0.003)
Dum2006	0.117**	(0.020)	0.090**	(0.050)	0.094**	(0.035)
Dum2007	0.083	(0.273)	0.056	(0.438)	0.062	(0.371)
Dum2008	0.027	(0.801)	-0.004	(0.972)	-0.001	(0.989)
Dum2009	-0.017	(0.890)	-0.056	(0.644)	-0.058	(0.621)
Constant	33.423***	(0.000)	33.583***	(0.000)	31.450***	(0.001)
Number of obs	180		180		180	
Number of groups	6		6		6	
Centered R2	0.637		0.631		0.632	
Uncentered R2	0.962		0.959		0.959	
Jacque-Bera test Prob>chi2			(0.000)			
Hausman test Prob>chi2	(0.840)		(0.842)		(0.858)	
Kleibergen-Paap rk LM statistic	(0.036)		(0.096)		(0.004)	
Anderson-Rubin Wald test Prob>chi2	(0.085)		(0.364)		(0.003)	
Hansen J statistic Prob>chi2	(0.170)		(0.537)		(0.191)	

Note: Heteroscedastic-consistent *p-value* in parentheses, with ***, ** and * denoting significance at 1, 5 and 10 percent level, respectively

Table 3.4: Pollution-spillover driven and capital-competition driven strategic interactions

Y= SO2 per capita	SO2 transport matrix		Industrial structure similarity matrix		SO2 transport matrix + Industrial structure similarity matrix	
$\sum \mathbf{W}_{\mathbf{Tij}} Y_{ijt}$	-0.960*	(0.075)			-0.938**	(0.049)
$\sum \mathbf{W}_{\mathbf{Iijt}} Y_{ijt}$			1.831***	(0.006)	2.056**	(0.013)
GRP3	-0.102***	(0.000)	-0.102***	(0.000)	-0.115***	(0.000)
GRP2	2.244***	(0.000)	2.325***	(0.000)	2.585***	(0.000)
GRP	-16.286***	(0.000)	-17.580***	(0.000)	-19.285***	(0.000)
Density	-0.111	(0.388)	-0.046	(0.726)	-0.078	(0.517)
State	1.127	(0.240)	1.425	(0.123)	1.344	(0.197)
Open	-0.327**	(0.038)	-0.336**	(0.034)	-0.380**	(0.027)
FDI	-1.413	(0.213)	-1.336	(0.227)	-1.688	(0.162)
Letters	0.000	(0.991)	0.004	(0.544)	0.003	(0.675)
Edu	1.367	(0.196)	1.070	(0.262)	1.664	(0.137)
Dum2005	0.242***	(0.001)	-0.123	(0.215)	-0.059	(0.586)
Dum2006	0.241***	(0.003)	-0.108	(0.338)	-0.059	(0.617)
Dum2007	0.114	(0.240)	-0.063	(0.533)	-0.074	(0.487)
Dum2008	-0.045	(0.757)	-0.002	(0.988)	-0.076	(0.546)
Dum2009	-0.166	(0.365)	0.022	(0.857)	-0.101	(0.517)
Constant	49.550***	(0.000)	39.998***	(0.000)	47.400***	(0.000)
Number of obs	180		180		180	
Number of groups	6		6		6	
Centered R2	0.549		0.575		0.522	
Uncentered R2	0.941		0.936		0.941	
Jacque-Bera test Prob>chi2			(0.000)			
Hausman test Prob>chi2	(1.000)		(0.999)		chi2<0	
Kleibergen-Paap rk LM statistic Prob>chi2	(0.002)		(0.000)		(0.007)	
Anderson-Rubin Wald test Prob>chi2	(0.037)		(0.001)		(0.001)	
Hansen J statistic Prob>chi2	(0.610)		(0.554)		(0.597)	

Note: Heteroscedastic-consistent *p-value* in parentheses, with ***, ** and * denoting respectively significance at 1, 5 and 10 percent level

The first column of Table 3.4 presents estimation results when the SO2 transport matrix is solely used. Obviously, *ceteris paribus*, receptor provinces respond negatively to SO2 emission changes in source provinces: a 1% increase (decrease) of

SO2 emission in weighted source provinces would lead a receptor province to decrease (increase) its own SO2 emission by 0.96%. This result is consistent with intuition because an increase of SO2 emission in "upwind" source provinces will increase the deposition of this pollutant in "downwind" receptor provinces through the spillover effect. As a result, more damages will be caused to receptor provinces' physical assets or public health by trans-boundary SO2. The governments of receptor provinces, with either economic or welfare concern, would reduce their own SO2 emission in order to compensate the perverse effect of the increased trans-boundary pollution. On the contrary, if source provinces reduce their SO2 emission, it is possible that growth-seeking receptor provinces would take the liberty to increase their own without generating greater damage to economy or public health. However, it is notable that this negative strategic interaction is not very significant (with a p-value of 7.5%).

One possible reason may explain the weak significance of pollution-spillover driven strategic interaction: although the weighting matrix used here is a province-to-province source-receptor matrix which traces SO2 transport, it is likely to be correlated to other patterns of interaction, e.g. the industrial structure similarity matrix. In fact, in spite of the long distance that SO2 can travel, the spillover-effect is decreasing with distance, i.e., in general, spillover is stronger among provinces which are geographically closer to each other.[71] Meanwhile, it is not uncommon that provinces geographically closer to each other have similar industrial structure, either due to market integration or similar resource endowments. Consequently, if the transport matrix and the industrial structure similarity matrix are correlated to each other, the sole use of the former may produce biased results for pollution-spillover driven strategic interaction.

In order to overcome this problem, two other regressions are made: one regression with the industrial structure similarity matrix only and the other with the transport matrix and the industrial structure similarity matrix jointly. The second

[71] Nevertheless, it is notable that the relation between spillovers and distance is not linear due to meteorological interference.

column of Table 3.4 reports results with only the industrial structure similarity matrix. The positive and strongly significant coefficient associated with the spatially lagged dependent variable suggests that the capital-competition driven strategic interaction is always present and significant, with an elasticity of 1.831. Given that the dependent variable - SO2 emission per capita- is a result of environmental enforcement, the positive interaction found in this case can be seen as a consequence of capital competition. The third column of Table 3.4 reports results with jointly the industrial structure similarity matrix and the transport matrix. One can note that everything else being equal, capital-competition driven and pollution-spillover driven strategic interactions coexist when provinces decide their SO2 emission level. While a change in “upwind” source provinces affect negatively and significantly the pollution level of “downwind” receptor provinces (with an elasticity of -0.938), capital-attracting competitors respond positively to each other’s pollution level change. The null hypothesis of zero strategic interaction can be rejected at the confidence level of 5% in both cases. It is also interesting to observe that the elasticity of capital-competition driven strategic interaction has risen from 1.831 to 2.056 once the pollution-spillover effects are taken into account; although a stronger pollution-spillover driven strategic interaction hasn’t been observed after integrating the capital-competition effects, it does become more significant. These interesting findings suggest that the two matrices are indeed correlated to each other.

3.5 Concluding remarks

Critics of decentralization often argue that, either due to capital competition or pollution spillovers, strategic interaction among jurisdictions in environmental policymaking may lead to inefficient environmental regulation stringency. Although this subject has been extensively studied in the U.S. context, very little attention has been given to the case of China. This chapter contributes thus to the environmental federalism literature in addressing the question of whether Chinese provinces engage in strategic environmental policymaking.

More specifically, two theoretical assumptions, the capital-competition driven strategic interaction and the pollution-spillover driven strategic interaction, are examined. It seems that both of these assumptions are high likely to hold in China.

First, using Chinese provincial data and spatial panel econometric methods, I find that Chinese provinces do engage in strategic interaction when they set their pollution levy. Moreover, this strategic interaction is positive and particularly strong among provinces with similar industrial structure (i.e., potential competitors for attracting mobile capital). Furthermore, evidence of asymmetric responsiveness suggested by the race to the bottom theory hasn't been found. Provinces respond strategically no matter whether they are at an advantage or a disadvantage in the capital competition. Finally, the one-sided fiscal decentralization arrangements may strengthen this capital-competition driven strategic interaction.

Secondly, using a SO2 transport matrix, I find that Chinese provinces also engage in pollution-spillover driven strategic interaction when they pollute. Particularly, the change of SO2 emission level in "upwind" source provinces affect negatively and significantly the pollution level of "downwind" receptor provinces. Moreover, the pollution-spillover driven strategic interaction and the capital-competition driven strategic interaction are likely to coexist when provinces decide their SO2 emission level.

Together with what has been found in Chapter 2, results found in this chapter call for once again a skeptical attitude on the decentralization of environment policy implementation in China. The strategic interaction among provinces driven either by capital competition or by pollution spillovers could be one of the reasons for China's inefficient environmental governance. Moreover, the current one-sided fiscal decentralization is likely to strengthen this phenomenon. As a result, it would be of great importance to develop more appropriate institutions for environmental protection and resource allocation in this county, where special attention should be paid to both vertical and horizontal inter-jurisdictional relations.

Appendix 3.1: Industrial structure similarity index (UNIDO, 1979)

In order to construct the industrial structure similarity matrix, the industrial structure similarity index proposed by UNIDO (1979) is used. This index can be calculated as follows:

$$S_{ijt} = \frac{\sum_{k=1}^{n} X_{ikt} X_{jkt}}{\sqrt{\sum_{k=1}^{n} X_{ikt}^2 \sum_{k=1}^{n} X_{jkt}^2}}, \qquad i = 1, ..., N, \quad j \neq i, \quad t = 1, ..., T$$

where i and j denote provinces, t denotes the year, S_{ijt} is the industrial structure similarity index between province i and province j, k denotes the industry, X_{ikt} and X_{jkt} denote the employment number (or added value) in (created by) industry k in provinces i and j, respectively. S_{ijt} has a value between zero and one and increases with the similarity level between province i and province j. S_{ijt} takes the value "one" when province i and province j have exactly the same industrial structure. In this study, default of sectorial added value data in several years, we calculte S_{ijt} with employment data of 27 industrial sectors published in China Industrial Economic Statistical Yearbook (2005-2010). These 27 sectors are: production and supply of electric power and heat power, manufacture of electrical machinery and equipment, manufacture of textile wearing apparel, foot ware and caps, manufacture of textile, mining and processing of nonmetal ores, manufacture of nonmetallic mineral products, mining and processing of ferrous metal ores, smelting and pressing of ferrous metals, manufacture of chemical fibers, manufacture of raw chemical materials and chemical products, manufacture of transport equipment, manufacture of metal products, mining and washing of coal, processing of food from agricultural products, processing of petroleum, coking, processing of nuclear fuel, manufacture of foods, manufacture of beverages, manufacture of communication equipment, computers and other electronic equipment, manufacture of general purpose machinery, manufacture of tobacco, manufacture of medicines, manufacture of measuring instruments and machinery for cultural activity and office work, mining and processing of non-ferrous metal ores, smelting and pressing of non-ferrous metals, manufacture of paper and paper products, and manufacture of special purpose machinery.

Appendix 3.2: SO2 transport matrix

The SO2 transport matrix used in this chapter is a province-to-province source-receptor matrix. In this (30×30) matrix, each column denotes a source province while each row denotes a receptor province. The value w_{ij} taken by the interception of column j and row i is calculated as follows:

$$w_{ij} = \frac{SO_{x(j\to i)}}{\sum_{j\neq i} SO_{x(j\to i)}}, \qquad i = 1,\ldots,N, \qquad t = 1,\ldots,T$$

where $SO_{x(j\to i)}$ is the sulfur deposition in receptor province i caused by transported SO2 emission discharged by source province j. The rows of matrix are normalized. Thus, w_{ij} measures the share of province j in the total sulfur deposition in province i which is caused by trans-boundary SO2. The greater w_{ij} is, the more effects province j's emission will have on the sulfur deposition in province i. As a result, this transport matrix allows calculating, for each downwind receptor province, the weighted average SO2 emission of its upwind provinces.

Data used to construct this transport matrix are abstracted from the Regional Air Pollution Information and Simulation (RAINS-ASIA) model (7.52).[72] The RAINS-ASIA 7.52 model is a tool developed by the International Institute for Applied Systems Analysis (IIASA) to analyze cost-effective strategies for reducing environmental impacts of SO2 emissions in Asia. In order to calculate acid deposition fields across Asia, this model employs interesting transfer matrices which can be used to simulate source-to-receptor SO2 dispersion scenarios. These (linear) transfer matrices are constructed from results of the long-range atmospheric transport model, providing information of the dispersion of pollutants from the various sources to about 2.5 thousand land-based grid cells of the modeling domain using the 1 degree

[72] More information on RAINS-ASIA can be found on the following website: http://www.iiasa.ac.at/~heyes/docs/rains.asia.html.

longitude * 1 degree latitude grid. Transfer matrices are calculated for the meteorological conditions of 6 years (1990-1995).

In fact, using these matrices and emission data of large point sources of emission of different years, the model allows simulating the sulfur deposition scenarios, i.e., spatial dispersion of SO2 contributed by individual sources can be identified in terms of deposition. For the purpose of this chapter, dispersion scenarios are simulated for each province with 2005 emission data[73] and transfer matrices based on average meteorological conditions of 6 years (1990-1995).[74]

In the case of China, sources can be identified at provincial level; however, the model doesn't allow identifying the deposition by province, because the spatial distribution in terms of deposition is only reported by 1 degree longitude * 1 degree latitude grid cell. In other words, the model gives only province-to-grid transfer information. As a result, in order to construct the province-to-province SO2 transport matrix, grid cells have to be identified and aggregated into provinces. Fortunately, the model provides matching information between grids and provinces; unfortunately, provinces have irregular boundaries thus many grids are divided by several (2, 3 or 4) provinces. In this case, the grid cell is assumed to be equally shared by provinces and the deposition is divided by the number of provinces which share the grid cell. Certainly, this treatment of shared grid cells is a simplistic one. It can be further improved using GIS data.

For illustrative purpose, the contribution of different provinces to the sulfur deposition in Beijing is presented in the following table.

[73] In fact, the model allows simulation with emission data of different years (1990, 1995, 2000, 2005, 2010, etc.). 2005 data are selected because this year is during the study period of this chapter and is considered to better fit the pollution transport over this period.

[74] It is notable that the use of "source to grid" transfer matrices implicitly assumes that the spatial relative distribution of emissions within a country will not dramatically change in future. Analysis undertaken at IIASA indicates that the error in computed deposition introduced by this simplification lies within the general range of model uncertainties when considering long-range transport.

Receptor (downwind) province: Beijing	
Source (upwind) provinces:	Contributions:
Hebei	56.59%
Shanxi	16.30%
Tianjin	10.45%
Shandong	4.84%
InnerMongolia	4.21%
Shaanxi	2.53%
Henan	2.43%
Gansu	0.93%
Ningxia	0.51%
Liaoning	0.36%
Jiangsu	0.26%
Sichuan	0.23%
Qinghai	0.10%
Anhui	0.10%
Xinjiang	0.09%
Hubei	0.05%
Chongqing	0.02%
Shanghai	0.01%
Jilin	0.01%
Heilongjiang	0.00%
Guizhou	0.00%
Zhejiang	0.00%
Beijing	0.00%
Fujian	0.00%
Guangdong	0.00%
Guangxi	0.00%
Hainan	0.00%
Hunan	0.00%
Jiangxi	0.00%
Yunnan	0.00%

Appendix 3.3: Variable names and significations

Variable names	significations
Y_1	Pollution levy per industrial added value (in log)
Y_2	SO2 emission per capita (tons per 10000 persons, in log)
wY_1	Spatially lagged Pollution levy per industrial added value (in log)
wY_2	Spatially lagged SO2 emission per capita (ton, in log)
GRP	Gross regional product per capita(USD at 2005 price, in log)
SO2intensity	SO2 emission per industrial added value (tons per 10000 USD at 2005 price, in log)
CODintensity	Chemical oxygen demand per industrial added value (tons per 10000 USD at 2005 price, in log)
Density	Population density (persons per km2, in log)
State	Proportion of industrial added value created by state-owned enterprises
Open	Ratio between the total trade and gross regional product
FDI	Ratio between actually used foreign direct investments and gross regional product
Letters	Number of complaint letters regarding environmental issues (in log)
Edu	Percentage of population with high education
IMB	Vertical fiscal imbalance indicator
Dum2005	1 if the year of 2005, 0 otherwise
Dum2006	1 if the year of 2006, 0 otherwise
Dum2007	1 if the year of 2007, 0 otherwise
Dum2008	1 if the year of 2008, 0 otherwise
Dum2009	1 if the year of 2009, 0 otherwise

Appendix 3.4: Summary Statistics

Variable	Obs.	Mean	Standard Deviation	Minimum	Maximum
Y_1	180	0.002	0.001	0.000	0.009
Y_2	180	210.667	127.326	25.463	649.562
GRP	180	2861.228	2075.915	511.462	11961.220
SO2intensity	180	0.233	0.215	0.017	1.150
CODintensity	180	0.058	0.072	0.001	0.547
Density	180	403.948	527.151	7.486	3029.969
State	180	0.451	0.191	0.059	0.834
Open	180	0.358	0.411	0.045	1.668
FDI	180	0.027	0.020	0.001	0.082
Letters	180	18231.950	19796.200	50.000	105942.000
Edu	180	0.072	0.050	0.025	0.289
IMB	180	0.520	0.185	0.141	0.930
Dum2005	180	0.167	0.374	0.000	1.000
Dum2006	180	0.167	0.374	0.000	1.000
Dum2007	180	0.167	0.374	0.000	1.000
Dum2008	180	0.167	0.374	0.000	1.000
Dum2009	180	0.167	0.374	0.000	1.000

Appendix 3.4: Nonlinear Marginal effects conditional on *IMB*

	Overall	2004	2005	2006	2007	2008	2009
Mean	2.964	3.029	2.950	2.948	2.969	2.937	2.952
Minimum	2.165	2.300	2.262	2.241	2.187	2.165	2.203
Lower quartile	2.626	2.668	2.621	2.571	2.530	2.540	2.631
Median	3.078	3.129	3.063	3.067	3.111	3.078	3.045
Upper quartile	3.214	3.290	3.143	3.161	3.205	3.219	3.222
Maximum	3.827	3.827	3.759	3.637	3.623	3.674	3.605
S.D.	0.390	0.378	0.379	0 .378	0 .421	0.416	0.393
Observation number	180	180	180	180	180	180	180

Chapter 4 Political incentive and provincial environmental performance in China

4.1 Introduction

In the environmental federalism literature, the third opponent argument against decentralization of environmental policy is related to “public choice” rationales.

In effect, until very recently, China’s local EPBs have been subordinated to local governments, both organizationally and financially. Evaluated on the base of economic-performance, local governments’ main concern has primarily been for economic growth. Given the structural conflict between economic growth and environment, local protectionism in favor of polluting but wealth creating enterprises has spread across the country. It seems that until very recently, the Chinese vertical bureaucratic system had created on a local political market great political incentive for local officials to develop economy at the cost of environment. Fortunately, things have begun to change little by little. Since 2006, the central government has attached priority to environmental protection in the national development strategy. New “pro-environment” political targets were about to be integrated in the bureaucratic system.

In this Chapter, following these related rationales, I study whether the Chinese bureaucratic system has contributed to ineffective environmental regulatory enforcement at sub-national level. I also examine whether recent changes on the Chinese political market have effectively modified the political incentive at provincial level. The rest of Chapter 4 is organized as follows. Section 2 is devoted to the description of the institutional context of Chinese political economy of environment. I present the bureaucratic system, its potential contributions to environmental policy failures, and some recent changes within this system since 2006; in section 3, some literature on political economy of environment is reviewed; in section 4, I present the estimation strategy to test for the effect of political incentive on Chinese provincial environment performance. Estimation results are reported in section 5 and in section 6 I conclude this chapter.

4.2 Institutional context of Chinese political economy of environment

In spite of the *de facto* federalism, Chinese central government's bureaucratic control over local politics has remained strong (Landry, 2008). The effectiveness of this bureaucratic control is fundamentally due to the centralized cadre system in China, where local officials are formally appointed by the central government. As a result, even if Chinese local officials enjoy formal autonomy, they may still be primarily responsive to central mandates (Lan *et al.*, 2011). Because local officials have been evaluated on an economic-performance base, the bureaucratic system is considered to have provided local governments with strong political incentives to facilitate pro-market reforms and promote economy growth since 1978 (Li and Zhou, 2005). However, this system has also been criticized to make environmental protection suffer at local level (Wang, 2006/2007). It seems that local governments' environmental protection behaviors can be greatly affected by the bureaucratic system and the political incentives created by it.

4.2.1 Vertical personnel control system

China's political system is broadly composed of six layers of state administration: the center, provinces, prefectures, counties, townships and villages. The CCP has unopposed political power in China. It acts as the headquarters of the Chinese political system, which ultimately controls the mobility of government officials within the system. This highly centralized structure of personnel control remains intact even to this day (Li and Zhou, 2005).

The vertical personnel control is exercised by the CCP through its cadre system. It is well known that the CCP has a streamlined vertical hierarchy from county-level officials to the General Secretary.[75] The cadre system uses this existing vertical

[75] Constitution of the CCP art. 10(1) (2007), *available at* http://news.xinhuanet.com/english/200710/25/content_6944738.htm.

hierarchy to connect central and local governments through a responsibility and incentive system. Using this formal system, superiors within the Party evaluate lower-level officials' performance in political goals' achievement (Golding, 2011). Strict reward and punishment liability is attached to political officials for positive or negative results: Establishment of goals is often rewarded with promotions, bonuses, and public praise, while failure to meet goals leads to demotions, salary reductions, and public censure (Whiting, 2004). In effect, the cadre system is used by the CCP to incentivize a variety of political goals and to control the actions of state employees. It is considered that this system provides market signals within China's centralized political system (Qiu and Li, 2009).

This system has been used by the CCP since the creation of the P.R.C.[76] and has seen a great evolution during the last 62 years, especially in the evaluation criteria (Li and Zhou, 2005). Although numerical goals can be integrated into the system at the same time, there has always been one with the highest priority. Before the 1978 reforms, promotion of a local official depended largely on ideological conformity and military merit. As reformers came to dominate in the 1980s, targets increasingly focused on economic performance (Zhang, 2006). Although political loyalty remains important, local economic performance became the most important criterion for higher-level officials assessing lower-level officials (Li and Zhou, 2005).

There can be little doubt that, during the post-reform era, this economic-performance based vertical control system has given local governments strong incentives to promote economic growth. Facing the extremely pro-growth skewed incentive, it is predictable that local governments will naturally choose to put priority on economic growth rather than environmental protection. And it is not surprising that local governments intend to protect polluting but wealth creating enterprises. In short, since the 1978 reforms, the vertical personnel control system hasn't created effective and clear incentives for sub-national actors to insistently pursue environmental protection (Lan *et al.*, 2011). On the contrary, due to the structural growth-environment conflict, local governments have been rather

[76] In fact, evaluation and responsibility systems already existed in imperial China (Golding, 2011).

incentivized to sacrifice environment for economic growth.

4.2.2 M-form organizational structure

If the vertical personnel control system has provided local officials with incentives to compromise environment goals, the organizational structure of Chinese government has provided them with the autonomy to do so. Some scholars characterize the Chinese political system as a multidivisional-form (M-form) organizational structure[77] (Qian and Xu, 1993). Precisely, they describe the Chinese government as a multilayer, multiregional organization, with multilayer structure along vertical lines and multiregional structure along horizontal lines. Obviously, the multilayer structure is strictly coordinated to the vertical personnel control system, while the multiregional structure is closely linked to the *de facto* federalism. In this system, as argued by Qian *et al.* (2006), "self-contained units" (local governments) have the autonomy of implementing policy within a defined space.

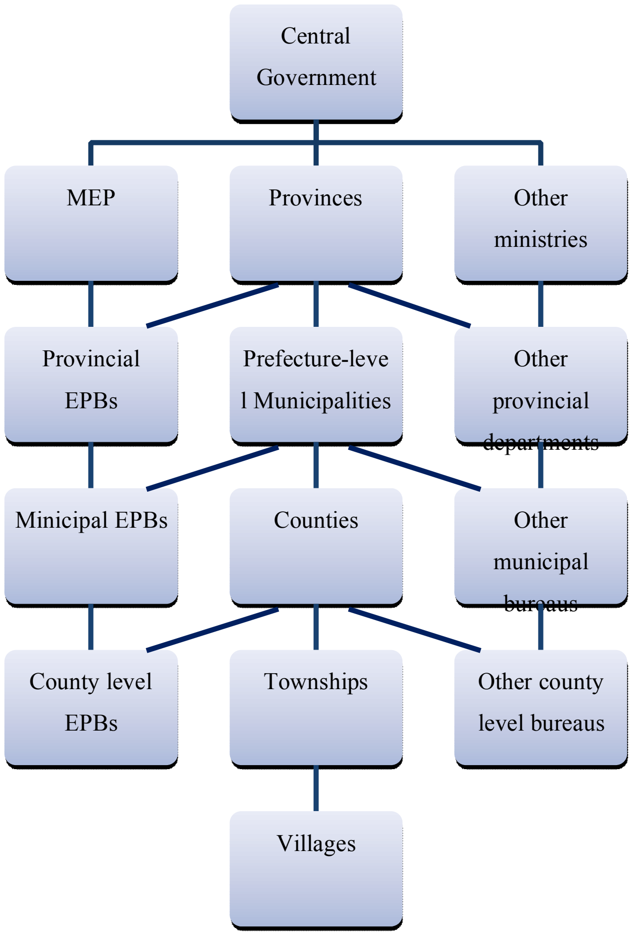
In terms of environmental policy, this M-form structure has endowed local governments with decisive influence to interfere with local environmental protection affairs. As stated in Chapter 1, EPBs have primary responsibility for implementing environmental policy at sub-national level. In spite of the vertical hierarchy within the MEP and EPBs, EPBs are part of the people's government at the same level and accountable to the latter. The sub-national institutional structure for environmental policy implementation in China is illustrated in Figure 4.1, where vertical hierarchical division and accountability relations are illustrated by beelines. Note that divisions of the same horizontal level have the same ranking position. According to Ma and Ortolano (2000), under decentralization, local governments have gained a greater control over local EPBs than the MEP. In practice, EPBs rely on local governments for virtually all their support, including their budgets, career advancement, number of personnel, and resources such as cars, office buildings, and employee housing. Given this substantial subordination of EPBs, local governments and non-environmental

[77] Qian *et al.* (2006) compare this "M-form" bureaucracy to more unitary bureaucracies, such as Russia's.

officials exert great influence on local environmental affairs. Consequently, local protectionism is widespread and pollution laws are too frequently ignored (Lan *et al.*, 2011).

Meanwhile, the so called M-form structure is indispensable for the vertical control system to work in China. The reason is that the M-form government structure makes each local leader's performance individually distinguishable and comparable and thereby, allows for a sensible link between performance and bureaucratic advancement (Li and Zhou, 2005). Under these conditions, it seems that the vertical political control and the M-form organizational structure have operated side-by-side in China and made up together a political framework in which local enforcement of environmental regulations has suffered so far.

Figure 4.1: Sub-national institutional structure for environmental policy implementation in China



4.2.3 New "pro-environment" changes in China's political framework

Fortunately, things have begun to change since 2006. It seems that Chinese central government has gained increasing awareness of the environmental damage severity in the country and the necessity to improve the environmental governance.

> *"We must be fully aware of the severity and complexity of our country's environmental situation and the importance and urgency of increasing environmental protection ... and environmental protection should be given a higher priority in the drive for national modernization."*
>
> Premier *Wen Jia-bao*,
> Address to the 6th National Conference on
> Environmental Protection, April 17, 2006

The year of 2006 has been a milestone. In this year, the CCP and the Chinese central government proclaimed an essential shift in state development policy priority, i.e., from quantity growth to quality growth with the purpose of building a harmonious, resource-efficient, and environment-friendly society (ADB, 2007). In the framework of this national development strategy, environmental protection has been placed at the top of the Government agenda.

In particular, the vertical personnel control system has seen new evolution. A State Council directive of December 2005 (The State Council of China, 2006) provided that environmental performance of local officials should be integrated into the personnel evaluation and control system during the period of the 11^{th} FYP in order to reflect scientific thinking on development. The 11^{th} FYEP explicitly states that China will "implement environmental target responsibility system and set up an examination mechanism on environmental management performance", that the system "will identify scientific assessment indicators and integrate them into the comprehensive evaluation system for the performance of party and government officials", and that an "environmental protection accountability and awarding & punishment system" will also be established. In practice, since 2005, experiments have been launched in several selected provinces in adding environmental performance into their local official evaluation schedules.[78] These new initiatives have been further confirmed by the amendments in 2008 to the Law on the Prevention and Control of Water Pollution (LPCWP),[79] where Article 5 of the LPCWP (2008) outlines that "the fulfillment of water environmental protection targets constitutes to be a part of the performance evaluation of local people's governments or their responsible persons".

Other illustrations of institutional changes after 2006 consist of the efforts made at the administrative level in order to address the conflicts between the vertical and horizontal lines in environmental governance. In 2008, the SEPA has been elevated to the MEP, with the purpose of strengthening the vertical control of the central government. Moreover, by December 2008, six regional supervision centers[80] had been established so as to ensure the implementation of central governmental standards, free of local interference and protectionism (OECD, 2006). The creation of the MEP and its regional offices reflects the willingness of the government to coordinate and align the disparate interests around environmental objectives at different levels.

[78] Three provinces are selected: Zhejiang, Shanxi and Hubei. http://www.yfzs.gov.cn/gb/info/FZGL/LDLS/2005-10/18/1733431052.html.

[79]http://www.lawinfochina.com/display.aspx?id=6722&lib=law&SearchKeyword=&SearchCKeyword=%CB%AE%CE%DB%C8%BE%B7%C0%D6%CE%B7%A8.

[80] Center of South China (Hubei, Hunan, Guangdong, Guangxi and Hainan), Center of Southwest China (Chongqing, Sichuan, Guizhou, Yunnan and Tibet), Center of Northeast China (Liaoning Jilin and Heilongjiang), Center of Northwest China (Shaanxi, Ningxia, Gansu, Qinghai and Xinjiang) and Center of North China (Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia and Henan). and of the East (Shanghai, Jiangsu, Zhejiang, Fujian, Anhui, Jiangxi and Shandong)

4.3 Literature review of political economy of environment: public choice of environmental policy

A large body of literature on political economy of environment tries to understand what determines the environmental policymaking in a specific political setting (Oates and Portney, 2003). This positive approach is primarily based on the public choice theory developed by Buchanan and Tullock (1962), which assumes that politicians are self-interested and seek to maximize their utility.

In the public choice literature, there is some consensus that election has an impact on “frontline" policy issues such as the level of government spending or the degree of income and wealth redistribution. However, skepticism exists on whether secondary policy issues, such as environmental policy, are influenced by electoral incentives (List and Sturm, 2006). Guided by this skepticism, lobby models have been widely used to understand the political economy of environment (Heyes and Dijkstra, 2001; Oates and Portney, 2003). These models focus on the strategic interaction between the incumbent and various interest groups and don’t explicitly model the election (List and Sturm, 2006). In a lobby model, lobbying groups offer contributions, and the government determines policy so as to maximize an objective function that includes as arguments both the general welfare of the electorate and the contributions from the interest groups (Oates and Portney, 2003). Aidt (1998), Fredriksson and Gaston (1999) and Damania and Fredriksson (2003) are interesting examples of lobby models in environmental policymaking.

Several other models consider the election more explicitly. For example, the median voter model, one of the most solidly established models in public choice, has been the most popular approach to the political economy of secondary issues (List and Sturm, 2006). Based on majority decision making, the median voter theorem states that, under certain assumptions, a politician will promote a certain policy corresponding to median voter’s demand in order to maximize his probability of being elected. As a result, the political outcomes are determined by the preference of the median voter. As demonstrated in Congleton (2002), the "strong form" median voter theorem[81] allows environmental policymaking to be modeled as a straightforward application of the rational choice model developed in microeconomics, where the median voter's preferred level of environmental regulation is obtained by maximizing his utility function. In this case, the environmental policymaking outcome predicted by the median voter theorem will be the one which equalizes the marginal cost of environmental regulation and the marginal benefit from more stringent environmental regulation for the median voter. McAusland (2003) also uses the median voter theorem to model the effects of openness and income inequality on individual and aggregate demand for pollution policy. Apart from the median voter model, some other election-incentive models, such as the partisan model (pioneered by Hibbs (1977)) and the political agency model (originated with Barro (1973)), assume that politicians will not always comply with the median voter's preference in their environmental policymaking. The partisan hypothesis assumes that parties competing for votes promise to implement programs that best serve the groups they represent (Bräuninger, 2005). While some earlier studies argue that the partisan hypothesis is not applicable to environmental policymaking in the U.S. (Buttel and Flinn, 1976; Ogden, 1971), more recent ones show that partisan differences do exist on environmental politics in the U.S., in that the Democratic Party is likely to be more "pro-environment" than its Republican counterpart (Dunlap and Allen, 1976; Gershtenson et al., 2006; Lester, 1980). Political agency models focus on the division of interest between the public and the offices holders (Barro, 1973). In these models where voters are imperfectly informed about government behavior, the role of several elements such as the electoral process, the turnover and the media, etc. is analyzed to explain the government's responsiveness and accountability (Besley and Burgess, 2002). List and Sturm (2006) construct a political agency model to explain that environmental policymaking across the U.S. states is determined by electoral incentives. They argue that, despite its secondary policy nature, environmental policy

[81] This strong form median voter theorem assumes that the preference of the median voter will be satisfied.

affects substantially a group of “single-issue voters”.[82] As a result, politicians may distort their policy choices in such secondary areas to attract additional “single-issue voters”. Their empirical results suggest that this manipulation of environmental policy depends on the term limit and the political competition degree. They find that the effort to attract additional “single-issue voters” decreases substantially when the governor is a lame duck, or when he has overwhelming support. Fredriksson *et al.* (2011) are also interested in the effect of term limits on environmental policy. Through a study on the differences in U.S. states’ environmental spending across both re-electable and lame duck governors from the two main political parties, they find that while re-electable governors do not set significantly different policies across parties, lame duck governors do. These results suggest that state politicians' environmental policy choices are primarily guided by holding office concerns and that re-election incentives matter.

4.4 A Chinese model of public choice of environmental policy

As reviewed above, most of existing literature on political economy of environment is more or less limited to the experience of countries with elected governments (Oates and Portney, 2003). The objective of this chapter is to examine how the political incentive created by the Chinese central government matters for environmental outcomes of Chinese provinces. For this purpose, I consider a political market within China’s centralized political system where the central government takes the place of the constituency and provincial leaders are submit to the vertical control system instead of the election. Before 2006， only economic performance was demanded by the central government and supplied by provincial leaders on this political market. Since 2006, both economic and environmental performances have been demanded. Following the public choice model, provincial leaders are considered to be self-interested and maximize their utility. Instead of the election incentives, the

[82] “Single-issue voters” are those who are substantially affected by a particular secondary policy. Their preferences over this policy are strong enough to induce them to vote for the politician considered most likely to implement their preferred policy on this particular issue (List and Sturm, 2006).

Chinese central government creates a political incentive of bureaucratic advancement and evaluates the performance of local leaders. This vertical control system provides market signals in that it incentivizes the tradeoff between economic and environmental performance according to the political targets of the central government.

Based on such a political market of provincial leaders, I study the effect of political incentive on environmental performance of Chinese provinces. Political incentive is difficult to quantify. Inspired by the reelection incentives and term limits models (Fredriksson *et al.*, 2011; List and Sturm, 2006), I examine indirectly this effect by studying how political competition degree and term limit affect provincial leaders' environmental performance. The basic idea behind this approach is simple. List and Strum (2006) show that concerns with environmental policy (as a secondary policy) decreases when the governor has overwhelming support; Both List and Strum (2006) and Fredriksson *et al.* (2011) find that reelection incentives decrease when the governor face term limit. Similarly, in the Chinese context, if political incentives did encourage environment-sacrificing growth, one should observe a differential responsiveness of leaders according to their political competitiveness; in particular, a less competitive leader would be more likely to conduct environmental-sacrificing behaviors, thus have a worse environmental performance than a more competitive one. Meanwhile, leaders facing term limit would be less responsive and redundant to conduct such environment-sacrificing growth. Moreover, recent changes in evaluation criteria of the bureaucratic system since 2006 consist of an ideal natural experiment to test for the change in political incentive effects. Following these ideas, three questions are investigated. First, does political competitiveness matter for a provincial leader's environmental performance? Secondly, are lame duck leaders redundant facing environment-sacrificing political incentives? And finally, have recent changes in evaluation criteria of the bureaucratic system mitigated these incentives since 2006?

4.5Empirical analysis

4.5.1 Data and Variables

A panel dataset of 30 Chinese provinces (Tibet, Hongkong and Macao excluded) over the period 1998-2010 is constructed for the present study. Data for tall variables are collected from China Statistical Yearbooks (NBSC, various volumes).

First of all, annual emission of SO2 is selected as indicator of the dependent variable- the environmental performance. China Statistical Yearbook publishes since 1998 annual emission level of SO2 for each province. SO2 is a main air pollutant in China. It is also the main cause of the acid rain, one of the essential control targets of the MEP. More importantly, SO2 reduction is one of targets of the 11th FYP (2006-2011), during which changes in bureaucratic evaluation criteria have occurred. As a result, SO2 is a good indicator to reflect the potential repercussion of political incentive changes since 2006.

There are two variables of interest in the present model, i.e., the political competitiveness and the term limit.

Li and Zhou (2005) show that the promotion of Chinese provincial leaders dependent essentially on their average economic performance during their term in office. As a result, one may expect that a provincial leader with a higher *ex-ante* average economic performance have greater political competitiveness, i.e. more probability to get bureaucratic advancement, *vice versa*. Following this idea, the *ex-ante* average economic growth rate during a leader's years in office ($AVGROWTH_{t-1}$) is calculated to measure his political competitiveness.

The binding term limit is not explicitly defined for provincial leaders in China; it is thus difficult to impose term limit constraint in this study as what is done in the U.S. context. In practice, although the official term of office is 5 years in China,[83] the

[83] The Chinese central government issued an official provision in 2006 which defined the office term limits for political leader. According to this provision, the official term of office is 5 years; a political leader cannot hold the same office for more than 2 terms; a political leader cannot hold offices of the same ranking for more than 3 terms. http://rjs.mca.gov.cn/article/rsgz/zcwj/gbrm/200804/20080400013722.shtml.

turnovers of provincial leaders are to the discretion of the central government. Depending on the decision of the central government, a provincial leader may move up to a higher ranking position, or be transferred to another equal ranking position, or terminate his office before the end of his official term[84]. Nevertheless, the mandatory retirement rule at the age of 65 was installed in China in 1982, which requires provincial leaders retire at the age of 65 if they are not promoted to higher positions in the central government. It is notable that although this rule is becoming more stringent, it is not always strictly enforced. Still considerable, if less and less, 65 year-old or older leaders occupy provincial offices. For illustration, about 25% of provincial leaders in Li and Zhou's (1979-1995) sample are 65 or older, compared to only 5% in my sample. After all, it seems that the age of 65 affects significantly a provincial leader's turnover probability (Li and Zhou, 2005). As a result, in this study, the age of 65 is used as a proxy of the term limit. One may expect that the political incentive created by the central government is less strong for provincial leaders of 65 years old or older, due to their *quasi* null probability to get bureaucratic advancement.

In order to construct the dummy variable *AGE65*, ages of provincial party secretaries (PPS) are collected. The dummy variable *Age65* is equal to "1" if the PPS is 65 or older, and "0" otherwise. Age information of all PPSs is collected from their C.V. published on the official website of News of the Communist Party of China.[85] Ages of the PPSs rather than those of provincial governors are used because the PPS is often considered as the most powerful person and *de facto* ruler of Chinese provinces. They are entrusted with the supervision of the provincial governments, and preside over huge provincial resources and economic development (Tan, 2004). In my sample, it is not uncommon that turnovers of PPSs take place in the course of the year. In this case, the month of the turnover is collected and the weighted age is calculated with the ages of the two PPSs before and after the turnover.

As control variables, GRP per capita, its squared and cubed terms are introduced.

[84] In the sample of the present study, about one third of provincial leaders don't finish their 5-year-official term (those who are retired due to the 65-age rule and those who are expelled from offices due to criminal penalty are not included.)

[85] http://cpc.people.com.cn/GB/64162/123659/7398342.html.

In order to rule out omitted variable bias, one year lagged provincial characteristic variables are also introduced because they may be correlated to both *SO2* and $AVGROWTH_{t-1}$. These lagged variables include FDI, trade openness, population density, urbanization, importance of industrial sector, education, unemployment rate and fixed capital store density. GRP per capita are deflated and converted to USD at constant price of 2005. In addition, provincial and time specific effects are included. Definitions and descriptive statistics of variables are presented in Appendices 4.1 and 4.2.

4.5.2 Estimation strategy: EKC revisited

The effect of political incentive on environmental performance of Chinese provinces is examined by revisiting the EKC hypothesis. The EKC is proposed by the path-breaking work of Grossman and Krueger (1991), which postulates the existence of an inverse U-shape relationship between per capita GDP and measures of environmental degradation in studying the potential environmental impacts of the North American Free Trade Agreement (NAFTA). Since then, the EKC hypothesis has been largely tested for, using different environmental indicators, different samples, different time series and different econometric methods, and has seen rather mixed results (Copeland and Taylor, 2004; Dinda, 2004; Stern, 2004). According to this EKC literature, relationship between per capita GDP and environmental variables may be determined by a series of concurring supply and demand side factors.

Question 1: Does political competitiveness matter for a provincial leader's environmental performance?

In order to investigate Question 1, the variable $AVGROWTH_{t-1}$ is included into the reduced form of the EKC, as specified in (4.1)

$$SO2_{it} = \beta_1 GRP_{it}^3 + \beta_2 GRP_{it}^2 + \beta_3 GRP_{it} + \beta_4 AVGROWTH_{t\text{-}1} + \delta_k X_{kit} + \mu_i + d_t + \varepsilon_{it},$$

$$t = 1,...,T, \quad i = 1,..., I, \quad k = 1,..., K \qquad (4.1)$$

where *i* denotes the province, *t* denotes the year, *SO2* is the per capita sulfur dioxide emission level, *GRP* denotes GRP per capita, $AVGROWTH_{t-1}$ is the age of the political leader of the province, *Density* is the population density, β and δ_k are two vectors of fixed but unknown parameters, X_{kit} is a vector of other control variables, μ_i is a cross-sectional specific effect which controls for all provincial time-invariant variables, d_t is a time specific effect which controls for all unobservable province-invariant omitted variables, and ε_{it} is an independently and identically distributed error term. Under this specification, the political incentive hypothesis will be proved if β_4 is negative and significant, i.e., everything else being equal, a provincial leader will have a worse environmental performance if the average growth rate is lower during his previous years in office, and *vice versa*.

Question 2: are lame duck leaders reluctant facing environmental-sacrificing political incentives?

The investigation of Question 2 requires the introduction of the term limit dummy variable- *AGE65*. In (4.2), (4.1) is augmented with *AGE65* and its interactive with the political competiveness variable $AVGROWTH_{t-1}$.

$$\begin{aligned} SO2_{it} &= \beta_1 GRP_{it}^3 + \beta_2 GRP_{it}^2 + \beta_3 GRP_{it} + \beta_4 AVGROWTH_{t\text{-}1} + \\ &\beta_5 AVGROWTH_{t\text{-}1} * AGE65 + \beta_6 AGE65 + \delta_k X_{kit} + \mu_i + d_t + \varepsilon_{it}, \\ &t = 1,\ldots,T, \quad i = 1,\ldots,I, \quad k = 1,\ldots,K \qquad (4.2) \end{aligned}$$

Under the specification of (4.2), the term limit hypothesis will be proved if β_4 is negative and significant, and β_5 is positive and significant, i.e., everything else being equal, due to the *quasi* null career prospect, a provincial leader with lower ex-ante economic performance score will be less environmental sacrificing (with a marginal effect of $\beta_4 + \beta_5$) than his younger counterparts (with a marginal effect of

β_4).

Question 3: Have recent changes in evaluation criteria of the bureaucratic system mitigated these incentives since 2006?

Question 3 addresses the natural experiment within Chinese bureaucratic system. If the political incentives have actually changed since 2006, one should observe a structural break at the year 2006, which can be tested for with the Chow test (Chow, 1960). Differential effects of political incentives can be compared by regressing with the two sub-samples (pre and post 2006).

Another issue to be considered in this EKC analysis is the potential endogeneity of GRP_t and $AVGROWTH_{t-1}$. As discussed in Stern (2004), endogeneity problem arises in EKC analysis if the environmental variable and per capita income are determined simultaneously, or if there are omitted variables that affect both the environmental variable and per capita income. In addition, although the lagged variable $AVGROWTH_{t-1}$ doesn't suffer from simultaneity bias, there may be omitted variables which are correlate to both *SO2* and $AVGROWTH_{t-1}$. In order to test for the potential endogeneity of these variables, Hausman test is performed with proper instruments (GRP_{t-1} GRP_{t-2} and $AVGROWTH_{t-2}$). Tests results reported in Table 4.1 and Table 4.2 suggest that these instruments are valid where the exogeneity of GRP_t and $AVGROWTH_{t-1}$ cannot be rejected at the 10% confidence level. As a result, panel estimators without IV are adopted in this analysis.

4.5.3 Estimation results

4.5.3.1 Political competitiveness

Estimation results of (4.1) for ***Question 1*** are presented in the first column of Table 4.1. Hausman test statistic allows a preference for the model with fixed effects. The coefficient associated with $AVGROWTH_{t-1}$ is negative and strongly significant (-0.631), suggesting that, *ceteris paribus*, a 1% decrease of ex-ante average growth rate (a worse economic performance) would lead to an increase of 0.631% in per capita SO2 emission, *vice versa*. This finding supports the political competitiveness hypothesis, according to which a less competitive political leader (with worse economic performance, in the Chinese context) would allow more pollution is his province, probably due to the environment-sacrificing political incentive.

Concerning control variables, it is notable that all the three terms of GRP per capita are statistically significant. The EKC takes an inverse "N" form instead of an inverse "U".

4.5.3.2 Term limit

In order to further investigate the repercussion of political incentive on provincial environment, term limit effects are considered in ***Question 2*** and estimated in (4.2). The model with fixed effects is preferred and results are reported in the second column of Table 4.1. Results obtained in this regression correspond exactly to what is predicted by the term limit hypothesis. In effect, the coefficient associated with the interaction $AVGROWTH_{t-1}$ $*AGE65_t$ is negative and significant, and the coefficient associated with $AVGROWTH_{t-1}$ is positive and significant. These results suggest that, *ceteris paribus*, the marginal effect of $AVGROWTH_{t-1}$ on *SO2* is negative (with a slope of -0.631 and significance at 1% level) for provincial leaders below 65; however, the marginal effect of $AVGROWTH_{t-1}$ on *SO2* becomes positive (with a slope of 3.828-0.631=3.197, significant at 5% level) when the provincial leader is 65 or older. Since 65 is the official retirement age, leaders over 65 have *quasi* null political career prospect. It seems that the political competitiveness disadvantage would not conduct a lame duck leader to be more environment-sacrificing, while it does incentivizes this kind of behavior among younger leaders. Moreover, the lame duck leader is likely to be more environmentally friendly when his ex-ante economic performance score is lower, for which the reason deserves further investigation.

Concerning control variables, the three terms of GRP per capita are statistically significant and have similar coefficients as in the former regression.

Table 4.1: Political competitiveness and term limit

	Political competitiveness		Term limit	
GRP	-0.102***	(0.010)	-0.104***	(0.007)
GRP2	2.256**	(0.012)	2.297***	(0.009)
GRP3	-16.619**	(0.015)	-16.952**	(0.011)
$AVGROWTH_{t-1}$	-0.631***	(0.000)	-0.631***	(0.000)
$AVGROWTH_{t-1}$ **AGE65*			3.828**	(0.019)
AGE65			-0.545**	(0.018)
L_FDI	1.898	(0.314)	1.795	(0.323)
L_OPENNESS	-0.078	(0.683)	-0.083	(0.633)
L_DENSITY	0.364	(0.557)	0.441	(0.469)
L_EDU	-1.342	(0.427)	-0.876	(0.598)
L_IND	0.738	(0.354)	0.802	(0.318)
L_URBAN	-0.947	(0.233)	-0.958	(0.218)
L_K/L	-0.021	(0.526)	-0.018	(0.602)
L_UNEMPLOY	0.838	(0.802)	0.698	(0.834)
D1999	-0.467	(0.359)	-0.576	(0.264)
D2000	-0.424	(0.393)	-0.532	(0.293)
D2001	-0.432	(0.368)	-0.547	(0.262)
D2002	-0.433	(0.341)	-0.542	(0.242)
D2003	-0.245	(0.563)	-0.348	(0.416)
D2004	-0.150	(0.677)	-0.243	(0.507)
D2005	-0.003	(0.992)	-0.082	(0.792)
D2006	0.034	(0.898)	-0.037	(0.891)
D2007	0.023	(0.912)	-0.033	(0.876)
D2008	-0.001	(0.992)	-0.039	(0.755)
D2009	-0.033	(0.678)	-0.055	(0.455)
Constant	44.238***	(0.009)	44.943***	(0.006)
Hausman test of endogeneity (prob>chi2)	(0.758)		(0.445)	
Kleibergen-Paap rk LM (prob>chi2)	(0.003)		(0.000)	
Hansen J test (prob>chi2)	(0.227)		(0.137)	
Hausman test of fixed effects (prob>chi2)	(0.000)		(0.000)	
R2 (within)	0.593		0.602	
N. of obs.	308		308	
N. of groups	30		30	

Note: Heteroscedastic-consistent *p-value* in parentheses, * p<0.1, ** p<0.05, *** p<0.01.

4.5.3.3 Structural break at 2006

The Chow test is performed in order to investigate incentives change assumed in ***Question 3***. The test statistic allows strongly rejecting the null hypothesis of constant or homogeneous estimation parameters before and after 2006, which suggests that the year 2006 does consist of a structural break point in the time series, probably due to the institutional changes discussed in Introduction.

With the purpose of comparing political incentive effects before and after 2006, two regressions are launched with the two subsamples respectively. Estimation results are reported in Table 4.2. Fixed effects models are always preferred. It is notable that over the period pre-2006, the variable $AVGROWTH_{t-1}$ has a positive and significant coefficient, which is consistent with the political competitiveness hypothesis. Before 2006, provincial leaders with lower *ex-ante* average growth scores would be more environmental detrimental, i.e., allow more per capita SO2 emission. However, it seems that this political competitiveness effect has vanished since 2006: everything else being equal, the marginal effect of $AVGROWTH_{t-1}$ on SO2 emission is not significantly different from zero in the period post-2006. This obvious contrast between the two periods separated by 2006 is a strong evidence of the political incentive change in that year. Since environmental performance has been integrated into the bureaucratic vertical evaluation criteria in 2006, political leaders have no longer interest to compensate their mediocre economic performance by compromising environment.

Concerning control variables, GRP terms have always significant effects on SO2 emission before 2006, and turn to be insignificant after 2006. Over the period pre-2006, the two turning points of GRP per capita occur at 619 USD and 1839 USD, i.e., pollution decreases with GRP per capita when the latter is below 619 USD (in 16% of observations before 2006), then increases with it until 1839 USD per capita (in 67% of observations before 2006), and finally decreases with it again above that level (in 17% of observations before 2006).

Table 4.2: Structural break at 2006

	1998-2005		2006-2010	
GRP	-0.195**	(0.016)	-0.048	(0.374)
GRP2	4.088**	(0.021)	1.076	(0.382)
GRP3	-28.328**	(0.027)	-7.975	(0.395)
AVGROWTH	-0.306***	(0.001)	0.116	(0.859)
L_FDI	2.584*	(0.077)	-2.981*	(0.066)
L_OPENNESS	0.232	(0.211)	0.153	(0.310)
L_DENSITY	1.006*	(0.063)	-0.268	(0.831)
L_EDU	-2.131	(0.227)	-3.074***	(0.001)
L_IND	-0.613	(0.409)	0.257	(0.473)
L_URBAN	0.112	(0.898)	-2.067**	(0.025)
L_K/L	0.004	(0.961)	0.044	(0.130)
L_UNEMPLOY	1.875	(0.551)	-6.127	(0.118)
D2000	0.039	(0.280)		
D2001	-0.007	(0.907)		
D2002	-0.031	(0.689)		
D2003	0.132	(0.257)		
D2004	0.189	(0.320)		
D2005	0.319	(0.210)		
D2006			0.196	(0.310)
D2007			0.154	(0.298)
D2008			0.055	(0.515)
D2009			-0.002	(0.960)
Constant	64.794**	(0.034)	26.896	(0.178)
Chow test (Prob > F)		0.000		
Hausman test of endogeneity (prob>chi2)	(0.551)		(0.505)	
Kleibergen-Paap rk LM (prob>chi2)	(0.014)		(0.001)	
Hansen J test (prob>chi2)	(0.119)		(0.825)	
Hausman test of fixed effects (prob>chi2)	(0.000)		(0.000)	
R2 (within)	0.585		0.827	
N. of obs.	188		120	
N. of groups	30		30	

Note: Heteroscedastic-consistent *p-value* in parentheses, * p<0.1, ** p<0.05, *** p<0.01.

4.6 Concluding remarks

It is argued that the economic-performance based personnel evaluation and the political incentive created by it has contributed to the large policy failure in environmental protection at sub-national level in China. In this chapter, inspired by the literature on political economy of environment, I study empirically effects of the bureaucratic system on environmental outcomes in this country. Precisely, three questions are investigated: (1) does political competitiveness matter for a provincial leader's environmental performance? (2) are lame duck leaders redundant facing environment-sacrificing political incentives? And (3) have recent changes in evaluation criteria of the bureaucratic system mitigated these incentives since 2006?

By revisiting the EKC hypothesis, first, I find that everything else being equal, a provincial leader will have a worse environmental performance if the average growth rate is lower during his previous years in office, and *vice versa*. These results suggest that political competitiveness of the PPS affects significantly his environmental performance. The less the PPS is competitive, the more he would compromise environment. Secondly, I find that this political competitiveness effect is significantly conditional on term limit. While a PPS younger than 65 would conduct such environment-sacrificing behaviors if he has less competitive economic performance score, a PPS of 65 or older would not do so because he has quasi *null* political career prospect. Finally, the structural break in 2006 is tested. It seems that recent changes in criteria of the personnel evaluation system since 2006 have effectively mitigated the former political incentive effects. In fact, because the central government has attached more importance to environmental performance, it is no longer as profitable as before for less competitive leaders to promote economic growth at the cost of environment. That's why the political competitiveness effect is only significant before 2006 and turns to be insignificant during the period post-2006.

Results found in this chapter suggest that provincial political leaders in China are also office motivated in the area of environmental policy, which is consistent with what have been found in the U.S. states (Fredriksson et al., 2011; List and Sturm, 2006). Given the economic-performance based bureaucratic evaluation criteria in the pre-2006 period, public choice rationales did incentive leaders to perform differently on environment according on their political competitiveness (the *ex-ante* growth scores in the Chinese context).

Appendix 4.1: Name and description of variables

Variable	Definition
SO2	SO2 emission per capita (tons per 10000 persons, in log)
GRP	Gross regional product per capita(USD at 2005 price, in log)
AVGROWTH	Average growth rate of a PPS's office years (no term accumulation)
Age65	1 if the PPS is 65 years old or older, 0 if not
L_FDI	One year lagged Foreign direct investments / Gross regional product
L_OPENNESS	One year lagged (Exportation + Importation) / Gross regional product
L_DENSITY	One year lagged population density (persons per km2, in log)
L_EDU	One year lagged population ratio with high education
L_IND	One year lagged industrial sector importance in total GRP
L_URBAN	One year lagged non-agricultural population/total population
L_K/L	One year lagged capital stock density (capital stock / total employment), constant price
L_UNEMPLOY	One year lagged Unemployment rate
D1999	1 if the year of 1999, 0 otherwise
D2000	1 if the year of 2000, 0 otherwise
D2001	1 if the year of 2001, 0 otherwise
D2002	1 if the year of 2002, 0 otherwise
D2003	1 if the year of 2003, 0 otherwise
D2004	1 if the year of 2004, 0 otherwise
D2005	1 if the year of 2005, 0 otherwise
D2006	1 if the year of 2006, 0 otherwise
D2007	1 if the year of 2007, 0 otherwise
D2008	1 if the year of 2008, 0 otherwise
D2009	1 if the year of 2009, 0 otherwise
D2010	1 if the year of 2010, 0 otherwise

Appendix 4.2: Summary statistics of variables

Variable	Obs	Mean	Std.dev	Min	Max
SO2	390	191.821	118.506	25.077	649.562
GRP	390	2262.026	2043.365	319.632	11862.610
AVGROWTH	328	0.113	0.049	0.051	0.900
Age65	390	0.049	0.216	0.000	1.000
L_FDI	390	0.029	0.028	0.001	0.169
L_OPENNESS	390	0.307	0.368	0.040	1.668
L_DENSITY	390	387.497	488.039	6.889	3029.969
L_EDU	390	0.056	0.044	0.008	0.289
L_IND	390	0.385	0.083	0.120	0.592
L_URBAN	360	0.336	0.159	0.143	0.883
L_K/L	360	1.887	2.286	0.109	11.843
L_UNEMPLOY	390	0.036	0.009	0.000	0.074
Dum1999	390	0.077	0.267	0.000	1.000
Dum2000	390	0.077	0.267	0.000	1.000
Dum2001	390	0.077	0.267	0.000	1.000
Dum2002	390	0.077	0.267	0.000	1.000
Dum2003	390	0.077	0.267	0.000	1.000
Dum2004	390	0.077	0.267	0.000	1.000
Dum2005	390	0.077	0.267	0.000	1.000
Dum2006	390	0.077	0.267	0.000	1.000
Dum2007	390	0.077	0.267	0.000	1.000
Dum2008	390	0.077	0.267	0.000	1.000
Dum2009	390	0.077	0.267	0.000	1.000
Dum2010	390	0.077	0.267	0.000	1.000

Chapter 5 Effects of one-sided fiscal decentralization on environmental efficiency of Chinese provinces

5.1 Introduction

As discussed in Chapter 1, the *de facto* environmental federalism and the one-sided fiscal decentralization in China have worked side by side in providing sub-national governments with the possibility and economic incentives to conduct ineffective enforcement of environmental policy. In Chapters 2, 3 and 4, I've tested empirically for hypotheses of free-riding, strategic interaction behavior and political incentive rationales. Results valid all of them and provide strong evidence of the inefficiency of the *de facto* environmental federalism in China. Moreover, results obtained in Chapter 3 suggest that the capital-competition driven strategic interaction would be reinforced by provincial fiscal imbalance. In this chapter, I'll further study the effects of the one-sided fiscal decentralization on environmental policy outcome in China, in terms of environmental efficiency.

The Tax Sharing System (TSS) reform on 1994 has recognized the dominant role of the central government in the intergovernmental fiscal system and recentralized fiscal revenues. However, expenditure responsibilities have been unrevised and remained largely decentralized. In 2009, 80% of national expenditures were spent by sub-national governments.[86] Decentralization is even more remarkable in environmental expenditures. In 2007, more than 95% of national expenditures on environmental protection were spent by sub-national governments, of which more than a half was realized at sub-provincial level.[87] In fact, the one-sided expenditure decentralization without revenue-side counterpart has created huge fiscal imbalance at the sub-national level in China. Local governments have excessively heavy expenditure responsibilities which are not met by their revenue assignments (World Bank, 2002). These governments depend largely on intergovernmental transfers, which are not always transparent or adequate. In 2009, 46.6% of sub-national expenditures come from central government's fiscal transfers. In the same year, the gap between revenues and expenditures accounts for 46.8% of the latter at

[86] Author's calculation based on China Statistical Yearbook, 2010.
[87] Author's calculation based on China Statistical Yearbook, 2008.

sub-provincial level.[88] The current one-sided fiscal decentralization may create strong constraints and disincentives for environmental protection. It is considered that with such important fiscal gap, localities, especially poor ones, would under-provide environmental service or conduct ineffective enforcement either due to fiscal incapacity, the unwillingness to compromise economic growth or the corruption (see more discussion in Chapter 1).

The actual effect of fiscal decentralization on environment is an empirical question with important political implications. However, very few studies have investigated this question empirically in the Chinese context with only two exceptions: Jiang (2006) explores with a case study why post-reform decentralization in China has failed to bring about environmental sustainability; Cui and Liu (2010) show that the increase of the disposable financial resources of local governments helps to control pollution sources with small externalities. This chapter tries to contribute to this part of literature in another approach, in estimating the effect of the one-sided fiscal decentralization on environmental efficiency of provincial gross product. It is straight forward to consider that, if the one-sided decentralization in China has effects on local environmental services provision and local environmental stringency, it is high likely to affect localities' environmental performance by modifying their pollution abatement efforts and polluting behaviors.[89]

Precisely, I estimate the environmental efficiency (*EE*) scores of the gross regional product (GRP) of Chinese provinces and examine whether provinces with larger fiscal imbalance have higher (or lower) *EE* scores. As defined later in the chapter, *EE* is the efficiency of environmentally detrimental variables in a production process. *EE* is chosen as the environmental performance indicator because it allows measuring environmental performance conditional on the levels of the output and other inputs.

The rest of this chapter is organized as follows. A brief literature review on *EE*

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[88] Author's calculation based on China Statistical Yearbook for Regional Economy (2010) and Finance yearbook of China (2010).

[89] Several studies show that environmental stringency in China has an important effect on polluting firms' behavior (Dasgupta *et al.*, 2001; Wang and Wheeler, 2005) and on local industrial pollution level (Wang and Wheeler, 2003).

models is made in section 2. A two-stage *EE* model is presented in Section 3. Section 4 is devoted to empirical analysis of the two-stage *EE* model. Conditional EE are calculated in section 5. Conclusions and political implications are formulated in Section 6.

5.2 Literature Review

5.2.1 Environmental efficiency models

To investigate the effects of fiscal decentralization on environment, a comprehensive environmental performance index must be developed and computed appropriately. In incorporating environmental variables into a traditional production function, environmental efficiency calculates have been proposed by a variety of studies. Based on adjustments of conventional measures of technical efficiency (*TE*), *EE* estimation methods can be classified according to two criteria. The first criterion distinguishes deterministic models from stochastic models, and the second criterion differentiates non-parametric models from parametric models. In the literature, two families of methods are widely employed, i.e. Stochastic Frontier Analysis (SFA) (Aigner *et al.*, 1977; Meeusen and Broeck, 1977) and Data Envelopment Analysis (DEA) (Charnes *et al.*, 1978). SFA is a parametric stochastic model based on economic theories, while DEA is a nonparametric deterministic model dispensable of specification forms. Each of these two approaches has its advantages and shortcomings (Hjalmarsson *et al.*, 1996). The present study will choose the SFA approach because industrial production is a specifiable process and more importantly, SFA is able to distinguish statistical noise from inefficiency and allows for a formal statistical testing of hypotheses. Moreover, to the knowledge of the author, most existing studies on Chinese *EE* have adopted the DEA approach (Zhang *et al.*, 2008; Yuan and Cheng, 2011; Zhang, 2009; Yang and Pollitt, 2009) except one (Wu, 2010). The present study will thus allow a comparison with their results.

Jointly produced with conventional desirable outputs, environmentally detrimental variables are particular because of their undesirable nature. In other words, in order to be efficient, a producer must maximize his conventional desirable outputs and minimize his environmentally detrimental factors as well as his conventional inputs. Given this particularity, two groups of technologies have been proposed to introduce environmentally detrimental variables into the production function. The first group treats them as undesirable outputs, while the second group considers them as inputs. Since DEA allows treating multiple output models, it is widely used in the first group of technologies.[90] Interesting attempts with SFA in the first group are realized by Cuesta *et al.* (2009) and Wu (2010), both of which rely on distance function models. The second group of technologies can be found in both DEA[91] and SFA studies. In the SFA approach, Reinhard *et al.* (1999; 2000) treat the environmentally detrimental variables as inputs to estimate the *EE* of Dutch dairy farms. Their method has been later adopted in numerous agricultural *EE* studies (Mkhabela, 2011; Reinhard *et al.*, 2002; Zhang and Xue, 2005).

5.2.2 Models of environmental efficiency determinants

Determinants of *TE* can be consistently estimated by the one-stage model proposed by Battese and Coelli (1995). However, this model isn't applicable to estimate the determinants of *EE* because *EE* is an adjusted measure of *TE*. To overcome this problem, a two-stage model is proposed by Reinhard *et al.* (2002) to analyze the sources of environmental efficiency variation. In the first stage, they use SFA to estimate *EE* scores of producers. In the second stage, they use again SFA to regress *EE* scores obtained in the first stage against a set of underground variables. According to the authors, a frontier approach in the second stage offers both economic and statistical advantages over an OLS or a TOBIT approach. The reason is as follows. First, conditional estimates of environmental efficiency scores can be derived from the one-sided error of the second stage SFA; secondly, while neither OLS nor TOBIT

[90] A comprehensive survey of such studies is made by Zhou *et al.* (2008).

[91] For example, (Hailu and Veeman, 2001) consider pollution as production input to study the efficiency of Canadian Pulp and Paper Industry. Yang and Pollitt (2009) consider SO_2 emission as input to estimate the efficiency of the Chinese coal-fired power sector.

allows estimating conditional *EE* scores, they are also biased and inconsistent if the conditional inefficiency exists.[92]

5.3 Two-stage SFA Model

The two-stage model of Reinhard *et al.* (2002) is chosen as the benchmark model for the following empirical analysis. In this section, first I illustrate the definition of *EE*. Secondly, *EE* estimation is developed in the framework of SFA. Finally, I present the second-stage model to estimate *EE* determinants and conditional *EE*.

5.3.1 Definition of *EE*

As defined in Reinhard *et al.* (2000), *EE* is the ratio of minimum feasible to observed use of environmentally detrimental inputs, conditional on observed levels of output and the conventional inputs. This definition is formulated in (5.1)

$$EE = \min\left\{\theta : F(X_k^R, \theta Z_l^R) \geq Y^R\right\} \tag{5.1}$$

where X_k^R and Y^R are observed vectors of conventional inputs and output. k is the number of conventional inputs. Z_l^R is the vector of observed environmentally detrimental inputs. l is the number of environmentally detrimental inputs. $F(\ )$ is the best practice production frontier. The *EE* measure θ is calculated as a radial contraction of the Z_l^R, conditional on $F(\ )$, X_k^R and Y^R.

5.3.2 Estimation of *EE* with SFA

EE defined in (5.1) can be estimated with a stochastic production frontier (5.2):

92 If the conditional inefficiency exists, disturbance term is skewed with non-zero mean.

$$Y_{it} = f(X_{kit}, Z_{lit}, \beta, \gamma, \zeta)\exp(V_{it} - U_{it}), \qquad t = 1,...,T, \quad i = 1,..., I \tag{5.2}$$

where for all producers indexed with a subscript i and for all years indexed with a subscript t,

Y_{it} is the output level;

X_{kit} is a vector of conventional inputs;

Z_{lit} is a vector of environmentally detrimental inputs;

β, γ and ζ are parameters to be estimated;

V_{it} is a symmetric random error term, independently and identically distributed as $N(0, \sigma_v^2)$, intended to capture the influence of exogenous events beyond the control of the industrial sector;

U_{it} is a non-negative random error term, independently and identically distributed as $N(0, \sigma_u^2)$, intended to capture time-variant technical inefficiency in production.[93]

A functional form has to be defined for the production function. In order to avoid excessive misspecification, the commonly employed flexible translog function[94] developed by Christensen *et al.* (1971) is used. Writing (5.2) in translog form gives (for convenience subscripts i and t are suppressed in (5.3), (5.4) and (5.5)):

$$\begin{aligned} \ln Y = \beta_0 + \sum_j \beta_j \ln X_j + \sum_k \gamma_k \ln Z_k + \frac{1}{2}\sum_j \sum_l \beta_{jl} \ln X_j \ln X_l \\ + \frac{1}{2}\sum_k \sum_m \gamma_{km} \ln Z_k \ln Z_m + \sum_j \sum_k \zeta_{jk} \ln X_j \ln Z_k + V - U \end{aligned} \tag{5.3}$$

[93] In this chapter, TE is measured with an output orientation.

[94] Compared to a Cobb-Douglas function whose output elasticities and RTS of inputs are constant, the translog function allows variable elasticities and RTS of inputs, which depend on input levels. Another reason to prefer a translog function to a Gobb-Douglas one is explained by Reinhard *et al.* (1999). In fact, if output elasticities of inputs are constant (as in a Cobb-Douglas function), a ranking by environmental efficiency scores would add no information to the technical efficiency measure because the two rankings would be identical. The two rankings can differ, and the environmental efficiency measure can add independent information of its own, only if output elasticities are variable (e.g. in a translog function).

where $\beta_{jl}=\beta_{lj}$; $\gamma_{jl}=\gamma_{lj}$. The logarithm of the output of a technically efficient producer is obtained by setting $U_{it}=0$ in (5.3). Since the environmental efficiency implies technical efficiency (Reinhard *et al.*, 1999), the logarithm of the output of an environmentally efficient producer is obtained by replacing Z with $EE\cdot Z$ and setting $U=0$ in (5.3), which gives (5.4):

$$\begin{aligned}\ln Y=\beta_0+\sum_j\beta_j\ln X_j+\sum_k\gamma_k\ln(EE\ Z_k)+\frac{1}{2}\sum_j\sum_l\beta_{jl}\ln X_j\ln X_l\\+\frac{1}{2}\sum_k\sum_m\gamma_{km}\ln(EE\ Z_k)\ln(EE\ Z_m)+\sum_j\sum_k\zeta_{jk}\ln X_j\ln(EE\ Z_k)+V\end{aligned}\tag{5.4}$$

Setting (5.3) and (5.4) equal permits the isolation of *lnEE* in (5.5):

$$\ln EE=\left[-b\pm(b^2-2U\sum_k\sum_m\gamma_{km})^{1/2}\right]/\sum_k\sum_m\gamma_{km}\tag{5.5}$$

where b is equal to the sum of the output elasticities with respect to the environmentally detrimental inputs. The b term is positive if the monotonicity conditions are fulfilled. In this function, the "+√" is applied because if $U=0$, only when the "+√" is used, the *lnEE* is equal to "0". U can be calculated from (5.6), the stochastic version of the output-oriented *TE*:

$$0\le TE_{it}=\frac{Y_{it}}{f(X_{it},Z_{it},\beta,\gamma,\zeta)\exp(V_{it})}=\exp(-U_{it})\le 1,$$

$$t=1,\ldots,T,\ i=1,\ldots,I\tag{5.6}$$

TE can be calculated using the Battese and Coelli (1988) estimator (5.7):

$$TE_{it} = E\left[\exp\left\{-U_{it}\right\} / (V_{it} - U_{it})\right] = \left[\frac{1-\Phi(\sigma_* - \mu_{*it} / \sigma_*)}{1-\Phi(-\mu_{*it} / \sigma_*)}\right] \exp\left\{-\mu_{*it} + \frac{1}{2}\sigma_*^2\right\}$$

$$t = 1,...,T, \quad i = 1,...,I \qquad (5.7)$$

where Φ ( ) is the standard normal distribution function, $\sigma_* = \sigma_u \sigma_v / (\sigma_u^2 + \sigma_v^2)^{1/2}$, and $\mu_{*it} = \left[\text{-}(V_{it} - U_{it})\sigma_u^2 + \mu\sigma_v^2\right] / (\sigma_u^2 + \sigma_v^2)$. Parameters $(\beta, \sigma_u^2, \sigma_v^2, \mu)$ are estimated using maximum likelihood techniques.

5.3.3 Estimate *EE* determinants and conditional *EE*

In order to examine effects of fiscal decentralization on *EE*, the second-stage SFA model proposed by Reinhard *et al.* (2002) has to be estimated. SFA is preferred here because it allows calculating environmental inefficiency with the one-sided error term, even after accounting for the underground variables (Greene, 1999). Conditional *EE* scores can thus be calculated. The second-stage frontier regression model can be expressed in the following general form:[95]

$$EE_{it} = G(W_{it}\ \delta)\ \exp\left\{V_{it}^* - U_{it}^*\right\}, \qquad t = 1,...,T, \quad i = 1,...,I \qquad (5.8)$$

where W_{it} is a vector of observed explanatory variables expected to influence EE_{it}, δ is a vector of parameters to be estimated, V_{it}^* $N(0, \sigma_{V_{it}^*}^2)$ and U_{it}^* $N^+(\mu^*, \sigma_{U_{it}^*}^2)$. In (5.8), the EE_{it} is assumed to be determined by three sources: (i) inefficiency explained by the observed underground variables captured by $G(W_{it}\ \delta)$; (ii) statistical noise reflected in V_{it}^*; and (iii) an unexplained environmental inefficiency reflected in U_{it}^*. Thus, as defined in (5.9), the conditional environmental efficiency CEE_{it} can be defined as $TE_{it}*$, the technical efficiency of (5.8), once effects of underground

95 A Cobb-Douglas function is used in this stage.

variables are taken into account.[96]

$$CEE_{it} = TE_{it}^{*} = EE_{it} / \left[G(W_{it};\delta) \cdot \exp\left\{V_{it}^{*}\right\} \right] = \exp\left\{-U_{it}^{*}\right\} \le 1,$$

$$t = 1,\dots,T, \quad i = 1,\dots,I \qquad (5.9)$$

5.4 Empirical analysis

5.4.1 Data and variables

Using data published in China Statistical Yearbook (2006-2011), China Statistical Yearbook for Regional Economy (2006-2010), Finance yearbook of China (2006-2010) and China Population Statistical Yearbook (2006-2010), the present study is based on a panel dataset of 30 Chinese provinces (and centrally administrated municipalities, Hongkong, Macao and Tibet excluded). China conducted a comprehensive national economic survey in 2004 and subsequently revised the country's GDP and GRP figures. As a result, the year 2004 marks a break in the time series of Chinese data. In order to avoid the bias caused by this break in *EE* estimation, the first-stage estimation (of *EE* scores) is based on the period of 2005-2010. The second-stage estimation (of decentralization effect) is base on the period 2005-2009, due to the data unavailability of several explicative variables in 2010.[97]

The output (*Y*) of the first-stage SFA model is the GRP of each province at constant price. The choice of this added value indicator as output indicator is conventional in macroeconomic efficiency such as total factor productivity (TFP) studies. Provincial capital stock (*K*) in constant prices,[98] total employment in each province (*L*) and the time trend (*T*) are three conventional inputs. *T* aims to capture

[96] Consider two producers with the same unadjusted *EE* scores. Assume that one produces under a more favorable external background than the other and that the background has an effect on both producers' performance. Then it is reasonable to think that the real *EE* score of the former would be inferior to that of the latter if external background variables are controlled. The same reasoning can be found in background variable models in the DEA framework (Fried *et al.*, 2002; William W. Cooper *et al.*, 2006)

[97] When the first draft of this paper was completed, 2010 statistics of several indicators (e.g. sub-provincial budgetary expenditures) in the 2nd-stage estimation were not yet published.

[98] Calculated by author following Zhang (2004).

technological progress. The environmentally detrimental input introduced in the model is the total energy consumption of each province. Energy consumption rather than other pollutants (e.g. CO2, SO2 or chemical oxygen demand) is chosen because, first of all, emission data of CO2 (the major greenhouse gas, which contributes to global warming) are not published in China. Although SO2 and chemical oxygen demand are relevant pollution in waste gas and wastewater, their statistics published in China Statistical Yearbook suffer from inaccuracies. In fact, China publishes a combination of survey data for all key industrial enterprises and estimation data for non-key enterprises,[99] both of which can be easily biased. Energy is an indispensable input of production. Due to the lack of better data, I use energy consumption as a proxy for air pollution. This treatment is common in environmental studies, for example, in Eskeland and Harrison (2003) and Dean *et al.* (2009). It is often believed that energy intensity of businesses is a major determinant of CO2 pollution, which is especially true in China where power generation still depends primarily on coal.[100] Finally, energy consumption data published in China Statistical Yearbook come from the energy balance sheets; Total energy consumption covers the energy consumption of the whole society, including that of village industries. These sheets are elaborated based on the law of conservation of energy, thus more reliable than pollution data.

In the second-stage model, EE scores obtained in the first stage are regressed against transfer's rate (*TR*) and fiscal gap (*FG*) respectively, as well as a set of control variables. The indicator *TR* is calculated as follows in equation (5.10):

$$TR_{it} = \frac{Transfers_{it}}{Expenditures_{it}}, \qquad t = 1,...,T, \quad i = 1,...,I \tag{5.10}$$

where i denotes the province, t denotes the year, $Transfers_{it}$ denotes the total fiscal transfers that province i receives from the central government in year t, and $Expenditures_{it}$ denotes the consolidated budgetary expenditures spent by province i in year t. The construction of *TR* is inspired by cross-country decentralization indicators

[99] China Statistical Yearbook (2011)

[100] In 2010, more than 70% of energy consumed in China was from coal (China Statistical Yearbook, 2011).

proposed by IMF's Government Finance Statistics (GFS), where vertical imbalance of a country is measured as transfers to sub-national governments as a share of sub-national government expenditures. In this chapter, *TR* indicates the degree to which a province relies on transfers to support its expenditures.[101] The indicator of *FG* is measured as follows in equation (5.11):

$$FG_{it} = \frac{\sum_{1}^{j} Expenditures_{ijt} - \sum_{1}^{j} \mathrm{Re}\,venues_{ijt}}{\sum_{1}^{j} Expenditures_{ijt}},$$

$$t = 1,\ldots,T, \quad j = 1,\ldots,J, \quad i = 1,\ldots,I \qquad (5.11)$$

where i denotes the province, t denotes the year, j denotes prefectures in province i, $Expenditures_{ijt}$ denotes consolidated budgetary expenditures spent by prefecture j of province i in year t. $Revenues_{ijt}$ denotes consolidated budgetary revenues raised by prefecture j of province i in year t. Default of transfers data at sub-provincial level, *FG* can also be considered as a proxy of vertical imbalance within a province, because prefectures need transfers to meet the gap between their expenditures and revenues.

Besides fiscal imbalance, a set of control variables which are likely to affect *EE* is also introduced into the 2nd-stage SFA. These variables include income per capita (*Dev*), population density (*Density*), trade openness (*Open*), foreign direct investment (*FDI*), education (*Edu*), urbanization (*Urban*), unemployment rate (*Unemployment*), state-owned sector importance (*State*), coast dummy (*Coast*) and year dummies (*D2006*, *D2007*, *D2008* and *D2009*). These variables are selected because, first, they are commonly used in micro, sectoral or macro studies as TFP determinants (Isaksson, 2007; Li and Hu, 2002; Beeson and Husted, 1989; Söderbom and Teal, 2004); Moreover, some of these variables, e.g. income per capita, population density, trade openness, foreign direct investment and education, are also frequently used as control variables in Environmental Kuznets Curve (EKC) studies (Gangadharan and

[101] Following the GFS indicator, VI doesn't distinguish conditional transfers versus general purpose transfers, due to data unavailability.

Valenzuela, 2001). If these variables may affect either productivity or environment, they are very likely to affect *EE*. Definitions and descriptive statistics of all variables are presented in Appendices 5.1 and 5.2.

5.4.2 Technical efficiency and non-adjusted environmental efficiency scores

TE scores necessary for *EE* calculation are maximum likelihood estimates computed with the software package *Frontier 4.1* developed by (Coelli, 1996). First, the time-variant translog stochastic production frontier with a normal-truncated normal error distribution was estimated. Tests of hypothesis for parameters are presented in Table 5.1. According to likelihood ration (LR) tests, the null hypothesis of absence of technical inefficiency $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2) = 0$ is strongly rejected. Nevertheless, the null hypothesis of half-normal distribution $\mu = 0$ and the null hypothesis of time-invariance cannot be rejected. Thus, the specification of time-invariant half-normal stochastic frontier is adopted to estimate the 1st-stage model.

Table 5.1: Tests of hypothesis for parameters

Specification	Null hypothesis	Tested against	Log likelihood	Likelihood ratio	$Prob > \chi^2$	Decision
1. Truncated-normal stochastic			313.671			
2. Absence of U_{it}	$\gamma = 0$	1	-2.215	631.771	0.000	rejected
3. Half-normal	$\mu = 0$	1	323.305	0.732	0.694	accepted
4. Time-invariant	$\mu = 0, \eta = 0$	3	312.035	2.540	0.111	accepted

All estimated parameters are reported in Table 5.2, which are used in the following to generate the *TE* and non-adjusted *EE* scores.

Table 5.2: Parameter estimates

Parameter	coefficient estimate	standard error	Parameter	coefficient estimate	standard error
β_0	24.469	8.528	β_{lt}	-0.013	0.009
β_k	0.998	0.575	γ_{ee}	0.089	0.040
β_l	-0.229	0.737	ζ_{ke}	-0.049	0.035
β_t	0.312	0.188	ζ_{le}	0.029	0.052
γ_e	-2.211	1.078	ζ_{te}	-0.011	0.012
β_{kk}	0.003	0.015	σ^2	0.402	0.113
β_{ll}	-0.011	0.029	σ_u^2 / σ^2	0.999	0.000
β_{tt}	0.002	0.001	μ	0	
β_{kl}	-0.004	0.030	η	0	
β_{kt}	0.004	0.005			

Note: The subscripts *k, l, t* and *e* refer to capital, labor, time trend, and energy consumption, respectively.

Table 5.3 reports elasticities of output with respect to each input. The sum of the mean output elasticities of four inputs indicates the presence of increasing returns to scale. The monotonicity assumption is violated for none of the inputs.

Table 5.3: Output elasticities

	Capital	Labor	Time	Energy	Total
Mean	0.123	0.079	0.051	0.856	1.108
Minimum	0.064	0.034	0.024	0.486	0.879
Lower quartile	0.096	0.065	0.038	0.786	1.064
Median	0.122	0.079	0.048	0.870	1.119
Upper quartile	0.143	0.094	0.059	0.947	1.161
Maximum	0.234	0.121	0.092	1.036	1.231
S.D.	0.034	0.020	0.016	0.115	0.071

Estimated *TE* and *EE* are summarized in Tables 5.4 and 5.5. *TE* scores vary from 27.4% to 98.8%, with a mean of 63.4%, in line with the findings of Zhang (2009). All in west China, Ningxia (27.4%), Guizhou (31.8%) and Qinghai (31.8%) have the lowest *TE* scores. Meanwhile, three of the most economically developed regions Guangdong (98.8%), Beijing (98.1%) and Shanghai (97.6%) have the highest *TE* scores. *EE* scores vary from 3.6% to 98.8%, with an overall mean of 57.3%. Over the period of 2005-2010, Ningxia (7.3%), Qinghai (7.4%) and Gansu (21.1%) have the lowest mean *EE* scores, while Guangdong (98.8%), Beijing (97.4%) and Shanghai (97.0%) have the highest mean *EE* scores. Nevertheless, these *EE* scores will be further adjusted.

*Table 5.4: Estim*ates of *TE* and non-adjusted *EE*

	Technical efficiency	Environmental efficiency
Overall mean	63.4%	57.3%
Overall minimum	27.4%	3.6%
Overall lower quartile	45.1%	41.0%
Overall median	61.2%	56.3%
Overall upper quartile	81.2%	76.4%
Overall maximum	98.8%	98.8%
Overall Standard Deviation (S.D.).	0.213	0.254
Overall observation number	180	177

Note: Three *EE*s cannot be solved.

Table 5.5: Estimates of non-adjusted *EE* by year

	2005	2006	2007	2008	2009	2010
Mean	57.2%	57.5%	56.4%	57.5%	57.1%	58.2%
Minimum	3.6%	4.9%	5.0%	8.9%	7.4%	8.5%
Lower quartile	47.6%	48.1%	40.1%	41.0%	40.5%	50.1%
Median	55.5%	55.9%	56.0%	56.9%	56.7%	57.7%
Upper quartile	75.3%	75.6%	76.0%	76.7%	76.4%	76.6%
Maximum	98.7%	98.7%	98.8%	98.8%	98.8%	98.8%
S.D.	0.255	0.253	0.263	0.256	0.259	0.258
Observation number	29	29	30	30	30	29
Dropped province	Qinghai	Qinghai	Na	Na	Na	Xinjiang

5.4.3 Effects of fiscal imbalance

Based on the 2nd-stage model presented in section 5.3.3, *EE* scores are regressed against *TR* and *FG*. Among the set of control variables, income per capita (*Dev*) and population density (*Density*) are put in logarithm. In order to be in line with EKC studies, cubed and squared income per capita (Dev^3 and Dev^2) are included.

5.4.3.1 Linear effects of *TR* and *FG*

First, linear effects of *TR* and *FG* are tested for. I start with a time-variant model where the distribution of the one-sided error is normal-truncated. Specification tests statistics are summarized in Table 5.6. According to the LR tests, for both *TR* and *FG*, the null hypothesis of $\gamma = 0$ is strongly rejected, indicating the presence of stochastic errors and the necessary to use the SFA model. The null hypothesis $\mu = 0$ can't be rejected at 5% level of significance. The null hypothesis of $\eta = 0$ is strongly rejected. As a result, the time-variant model with half-normal distribution is adopted for the 2nd-stage SFA.

Table 5.6: Specification tests for the 2nd-stage linear effect model

Indicator	Specification	Null hypothesis	Tested against	Log likelihood	Likelihood ratio	$Prob > \chi^2$	Decision
TR	1. Truncated-normal stochastic			456.362			
TR	2. Absence of U_{it}	$\gamma = 0$	1	94.290	724.144	0.000	rejected
TR	3. Half-normal	$\mu = 0$	1	456.006	0.712	0.399	accepted
TR	4. Time-invariant	$\mu = 0, \eta = 0$	3	450.870	10.271	0.001	rejected
FG	5. Truncated-normal stochastic			456.970			
FG	6. Absence of U_{it}	$\gamma = 0$	5	91.816	730.307	0.000	rejected
FG	7. Half-normal	$\mu = 0$	5	456.621	0.698	0.403	accepted
FG	8. Time-invariant	$\mu = 0, \eta = 0$	7	451.012	11.218	0.001	rejected

Table 5.7: Estimation with linear *TR* and *FG* effects

	With *TR*		With *FG*	
Constant	1.377*	(1.758)	1.407*	(1.797)
TR	0.006	(0.259)		
FG			0.019	(1.151)
Dev^3	-0.004**	(-2.356)	-0.004**	(-2.359)
Dev^2	0.088**	(2.268)	0.090**	(2.292)
Dev	-0.610**	(-1.990)	-0.626**	(-2.034)
Open	0.021**	(2.336)	0.019**	(2.171)
FDI	-0.194**	(-2.237)	-0.173**	(-1.966)
Edu	-0.113*	(-1.818)	-0.115*	(-1.938)
Unemployment	-0.165	(-0.595)	-0.164	(-0.622)
Urban	-0.056	(-0.925)	-0.062	(-1.035)
State	-0.097	(-1.441)	-0.098	(-1.489)
Density	0.127***	(5.850)	0.131***	(6.078)
Coast	0.127***	(11.114)	0.133***	(10.871)
D2006	-0.010***	(-4.384)	-0.010***	(-4.627)
D2007	-0.018***	(-4.355)	-0.018***	(-4.771)
D2008	-0.024***	(-3.464)	-0.025***	(-3.839)
D2009	-0.036***	(-4.246)	-0.038***	(-4.701)
σ^2	0.084***	(3.899)	0.085***	(4.052)
γ	1.000***	(13148.850)	1.000***	(13592.846)
μ	0		0	
η	0.006***	(3.126)	0.006***	(3.249)
Log likelihood function	456.006		456.621	

Note: *t-student* statistics between parentheses, *** significance at 1% level, ** significance at 5% level, * significance at 10% level.

Estimation results are presented in Tables 5.7. (Results with a truncated normal distribution can be found in Appendix 5.3.) Both *TR* and *FG* have positive and non-significant coefficients. These results suggest that fiscal imbalance would have no significant effects on *EE*, which goes against the prediction. However, insignificant linear effects of *TR* and *FG* are not surprising because fiscal imbalance may have different effects on *EE* in different circumstances. For example, poor localities may be more vulnerable facing fiscal pressures and sacrifice more easily environment. As a result, in the following, nonlinear effects of *TR* and *FG* on *EE* will be considered.

Concerning control variables, most of they have expected signs, among which squared income per capita, trade openness, population density and Coast dummy have positive and significant coefficients, while income per capita, cubed income per capita, FDI, illiterate rate and year dummies have negative and significant coefficients.

5.4.3.2 Nonlinear effects of *TR* and *FG*

In order to examine potential nonlinear effects of *TR* and *FG*, interactions between fiscal imbalance indicators and income per capita are created, namely $TR*Dev$ and $FG*Dev$. These interactions allow testing whether effects of fiscal imbalance on the *EE* of a province depend on its economic development level. The LR test statistics strongly reject the null hypothesizes that the coefficients β_{TR*Dev} and β_{FG*Dev} (associated respectively to $TR*Dev$ and $FG*Dev$) are equal to zero. This means that the specifications with interactions are more fit than those without interactions. Once again, the time-variant model with half-normal distribution is adopted. Specification tests statistics are summarized in Table 5.8. Regression results are presented in Table 5.9. (Results with a truncated-normal distribution can be found in Appendix 5.4.)

Table 5.8: Specification tests for the 2nd-stage nonlinear effect model

Indicator	Specification	Null hypothesis	Tested against	Log likelihood	Likelihood ratio	$Prob > \chi^2$	Decision
TR	1. Truncated-normal with nonlinear *VI*			464.771			
TR	2. Truncated-normal with linear *VI*	$\beta_{TR*GDP} = 0$	1	456.362	16.818	0.000	rejected
TR	3. Absence of U_{it}	$\gamma = 0$	1	94.405	740.732	0.000	rejected
TR	4. Half-normal	$\mu = 0$	1	464.675	0.193	0.661	accepted
TR	5. Time-invariant	$\mu = 0, \eta = 0$	3	459.907	9.536	0.002	rejected
FG	6. Truncated-normal with nonlinear *FG*			463.607			
FG	7. Truncated-normal with linear *FG*	$\beta_{FG*GDP} = 0$	6	456.970	13.274	0.000	rejected
FG	8. Absence of U_{it}	$\gamma = 0$	6	92.182	742.850	0.000	rejected
FG	9. Half-normal	$\mu = 0$	6	463.529	0.156	0.693	accepted
FG	10. Time-invariant	$\mu = 0, \eta = 0$	9	458.074	10.910	0.001	rejected

It is notable that when interactions are included, both *TR* and *FG* as well as their interactions with income per capita have significant coefficients, suggesting the significant nonlinear effects of fiscal imbalance on *EE*. Precisely, the marginal effects of *TR* and *FG* are conditional on income per capita. The more a province is affluent, the less fiscal imbalance is detrimental to *EE*, *vice versa.* These results seem to confirm the hypothesis that fiscal imbalance has more serious environmental consequences in poorer localities than in richer ones. In these two nonlinear-effect models, control variables have the same signs as in previous linear effect models, although different orders of income per capita become non-significant in *TR* regression.

Table 5.9: Estimates with nonlinear *TR* and *FG* effects

	With *TR*		With *FG*	
Constant	0.882	(1.203)	1.958***	(2.708)
TR	-0.529***	(-4.340)		
*TR * Dev*	0.071***	(4.478)		
FG			-0.362***	(-3.595)
*FG * Dev*			0.047***	(3.841)
Dev3	-0.001	(-0.910)	-0.004***	(-3.038)
Dev2	0.038	(1.020)	0.103***	(3.018)
Dev	-0.320	(-1.119)	-0.783***	(-2.883)
Open	0.011	(1.256)	0.004	(0.420)
FDI	-0.153**	(-1.890)	-0.170**	(-2.048)
Edu	-0.078	(-1.402)	-0.115**	(-2.109)
Unemployment	-0.126	(-0.497)	-0.091	(-0.363)
Urban	-0.006	(-0.126)	-0.031	(-0.872)
State	-0.088	(-1.432)	-0.097	(-1.577)
Density	0.144***	(11.681)	0.141***	(22.243)
Coast	0.142***	(12.449)	0.143***	(12.057)
D2006	-0.007***	(-3.208)	-0.007***	(-3.613)
D2007	-0.011***	(-2.914)	-0.013***	(-3.418)
D2008	-0.015**	(-2.337)	-0.017***	(-2.617)
D2009	-0.028***	(-3.648)	-0.031***	(-3.914)
σ^2	0.085***	(3.954)	0.084***	(3.813)
γ	1.000***	(15223.715)	1.000***	(15304.738)
μ	0		0	
η	0.005***	(3.085)	0.005***	(3.907)
Log likelihood function	464.675		463.529	

Note: *t-student* statistics between parentheses, *** significance at 1% level, ** significance at 5% level, * significance at 10% level.

5.4.4 Robustness considerations: endogenous income per capita

An important issue worth considering is the potential endogeneity of income per capita in the 2nd-stage SFA model. As discussed in Stern (2004), income per capita can be an endogenous explicative variable of environment. The endogeneity problem can arise in two ways. On one hand, there may exist simultaneous causality between income per capita and environment. On the other hand, there may exist missing explicative variables of environment which are also correlated with income per capita. In the present study, the endogeneity problem also calls for attention. First one may think that a more environmentally efficient province is more efficient in resource allocation thus has better economic performance; secondly it is possible that some unobserved variables, such as institution quality and demand for environment are correlated simultaneously with income per capita and *EE*. Unfortunately, to the knowledge of the author, no estimator has been developed to address endogeneity problem in the SFA framework. That's why several alternative models will be tried in the following in order to control the potential bias in the 2nd-stage model related to endogenous income per capita.

5.4.4.1 Two-stage least squares estimate

The first alternative model is a linear instrumental variable (IV) estimator. The linear IV also has the advantage of allowing controlling provincial fixed effects, which are not allowed in a TOBIT with instrumental variables.

In the model of Section 5.4.3.2, suspected endogenous variables are Dev^3, Dev^2, Dev, $TR*Dev$ and $FG*Dev$. Instruments used in the IV estimator include all of the internal exogenous variables in Table 5.9 plus the following external instruments: one-year lagged income per capita (*LDev*), squared one-year lagged income per capita ($LDev^2$), cubed one-year lagged income per capita ($LDev^3$), one-year lagged growth rate (*Lgrowth*), interaction between *TR* and *LDev* ($TR*LDev$) and interaction between *FG* and *LDev* ($FG*LDev$). These external instruments are assumed to affect *EE* only though suspended endogenous variables. The 2nd-stage results of the IV estimator are presented in Table 5.10. The first stage results and statistics of related tests are in Appendix 5.5. In the 1st-stage regression results, the Kleibergen–Paap LM and Wald tests reject their null hypotheses of under-identification. The Anderson–Rubin Wald test and Stock–Wright LM test reject their null hypothesis and indicate that the endogenous regressors are relevant. The Hansen J statistics can't reject the null hypothesis of the over-identification of all instruments. The null hypotheses of redundant instruments are also rejected. The IV estimator seems to be fit.

Table 5.10: IV estimates with provincial fixed effects (2nd- stage results)

	With *TR*		With *FG*	
TR	-0.471***	(-2.870)		
$TR * Dev$	0.066***	(2.950)		
FG			-0.292**	(-2.180)
$FG * Dev$			0.039**	(2.400)
Dev^3	-0.001	(-0.270)	-0.003	(-1.240)
Dev^2	0.020	(0.340)	0.075	(1.230)
Dev	-0.158	(-0.340)	-0.528	(-1.100)
Open	0.016	(1.270)	0.013	(0.970)
FDIi	-0.142	(-1.050)	-0.153	(-1.150)
Edu	-0.068	(-1.060)	-0.101	(-1.460)
Unemployment	-0.023	(-0.080)	0.079	(0.240)
Urban	0.014	(0.250)	-0.026	(-0.410)
State	-0.066	(-0.950)	-0.054	(-0.840)
Density	0.185***	(3.650)	0.207***	(4.140)
D2006	-0.009***	(-3.320)	-0.011***	(-3.610)
D2007	-0.018***	(-3.030)	-0.021***	(-3.580)
D2008	-0.026***	(-2.670)	-0.032***	(-3.210)
D2009	-0.041***	(-3.350)	-0.049***	(-3.810)
R^2	0.820		0.811	
Nb. of observations	148		148	

Note: Heteroscedastic-consistent *t-student* statistics between parentheses, *** significance at 1% level, ** significance at 5% level, * significance at 10% level.

Consistent with the results in Table 5.9, *TR*, *FG*, $TR * Dev$ and $FG * Dev$ have significant coefficients, suggesting the significant nonlinear effects of fiscal imbalance on *EE*. Marginal effects of *TR* and *FG* are conditional on income per capita. The more a province is affluent, the less fiscal imbalance is detrimental to EE, *vice versa.* Among control variables, population density and year dummies always have significant coefficients. Others although not significant, have similar signs to those in

Table 5.9.

5.4.4.2 SFA with lagged income per capita

The second and third alternative models stay in the SFA framework. The second one is to replace income per capita (*Dev*) by one-year lagged income per capita (*LDev*) in order to avoid simultaneous bias. Results of SFA with *LDev* are presented in Table 5.11. Once again, a time-variant half-normal specification is preferred by the LR tests. Specification tests statistics are reported in Appendix 5.6.

Table 5.11: SFA with *LDev* (2nd-stage results)

	With *TR*		With *FG*	
constant	1.458	(1.622)	2.485***	(2.943)
TR	-0.501***	(-3.666)		
*TR * LDev*	0.064***	(3.697)		
FG			-0.337***	(-3.156)
*FG * LDev*			0.043***	(3.344)
Dev^3	-0.003	(-1.307)	-0.005***	(-3.094)
Dev^2	0.063	(1.386)	0.122***	(3.097)
Dev	-0.522	(-1.482)	-0.956***	(-3.032)
Open	0.014*	(1.680)	0.009	(1.124)
Fdi	-0.163*	(-1.918)	-0.174**	(-2.098)
Edu	-0.069	(-1.175)	-0.108*	(-1.856)
Unemployment	-0.182	(-0.680)	-0.146	(-0.587)
Urban	0.015	(0.283)	-0.017	(-0.517)
State	-0.082	(-1.269)	-0.084	(-1.344)
Density	0.142***	(7.265)	0.141***	(20.030)
Coast	0.143***	(12.424)	0.144***	(12.382)
D2006	-0.007***	(-2.752)	-0.008***	(-3.590)
D2007	-0.012**	(-2.424)	-0.014***	(-3.395)
D2008	-0.008	(-1.284)	-0.011**	(-2.062)
D2009	-0.021***	(-2.636)	-0.025***	(-3.510)
σ^2	0.085***	(3.759)	0.084***	(3.857)
γ	1.000***	(14285.858)	1.000***	(14172.426)
μ	0		0	
η	0.005***	(3.112)	0.005***	(3.395)
Log likelihood function	460.107		459.316	

Note: *t-student* statistics between parentheses, *** significance at 1% level, ** significance at 5% level,

* significance at 10% level.

It is easy to see that the effects of fiscal imbalance indicators are always nonlinear and consistent with what have been found in previous specifications: marginal effects of *TR* and *FG* on *EE* are conditional on and offset by one-year lagged income per capita. Fiscal imbalance is less detrimental to EE provinces which had better economic performance in the last year, *vice versa.*

5.4.4.3 SFA with the control function method

The third alternative model to purge potential bias related to endogeneity is to use the control function method (Hausman, 1978).[102] In such a method, predicted residuals of the first-stage regression of the 2SLS (where suspected endogenous variables are regressed on exogenous instruments) are introduced into the original reduced form regression. Since predicted residuals are generated regressors, if their coefficients are significantly different from zero, their introduction can generate biased standard-errors which need be corrected (Pagan, 1984). However, the LR test statistics indicate that the introduction of these residuals don't make the second-stage SFA more fit. As a result, I consider that these generated regressors don't cause standard-error bias in the present model. Although not conventional in SFA practices, this control function method allows checking the robustness of previous results. Table 5.12 presents estimation results of SFA with predicted residuals. LR tests allow a preference for time-variant half-normal specifications. Specification tests statistics are reported in Appendix 5.7.

Once again, consistent results regarding the nonlinear effects of *TR* and *FG* on *EE* are obtained. These effects are conditional on and offset by economic development level of a province. Fiscal imbalance is less detrimental to EE in more affluent provinces, *vice versa.*

In summary, different specifications give consistent and comparable results, indicating that the nonlinear effects of fiscal imbalance on *EE* are robust. The

[102] An alternative method is to introduce predicted endogenous variables and bootstrap the standard-errors.

coefficients associated with *TR* vary around -0.5 (from -0.529 to -0.471); the coefficients associated with *FG* vary from -0.362 to -0.292; the coefficients associated with $TR*Dev$ vary from 0.063 to 0.071; and the coefficients associated with $FG*Dev$ vary from 0.039 to 0.047. All of them are significant.

Table 5.12: SFA with control function

	With *TR*		With *FG*	
Constant	0.865	(1.051)	1.574**	(1.969)
TR	-0.478***	(-3.886)		
$TR*Dev$	0.063***	(3.869)		
FG			-0.306***	(-3.132)
$FG*Dev$			0.041***	(3.439)
Dev3	-0.001	(-0.715)	-0.003**	(-2.116)
Dev2	0.035	(0.822)	0.083**	(2.155)
Dev	-0.294	(-0.909)	-0.631**	(-2.087)
Open	0.017*	(1.786)	0.011	(1.124)
Fdi	-0.152*	(-1.885)	-0.154*	(-1.886)
Edu	-0.084	(-1.462)	-0.117**	(-2.084)
Unemployment	-0.099	(-0.390)	-0.059	(-0.223)
Urban	-0.002	(-0.037)	-0.046	(-1.226)
State	-0.072	(-1.121)	-0.069	(-1.090)
Density	0.135***	(6.900)	0.141***	(21.858)
Coast	0.138***	(11.638)	0.143***	(12.179)
D2006	-0.006***	(-2.959)	-0.007***	(-3.611)
D2007	-0.011***	(-2.617)	-0.013***	(-3.427)
D2008	-0.014**	(-2.020)	-0.017***	(-2.561)
D2009	-0.026***	(-3.149)	-0.031***	(-3.613)
Residues Dev3hat	0.004	(0.558)	-0.001	(-0.145)
Residues Dev2hat	-0.083	(-0.531)	0.023	(0.154)
Residues Dev1hat	0.542	(0.444)	-0.250	(-0.215)
Residues $(TR*Dev)hat$	0.131**	(2.163)		
Residues $(FG*Dev)hat$			0.097*	(1.807)
σ^2	0.085***	(3.877)	0.084***	(4.509)
γ	1.000***	(16147.691)	1.000***	(18462.224)
μ	0.000		0.000	
η	0.005***	(3.270)	0.005***	(3.482)
Log likelihood function	468.405		467.771	

Note: *t-student* statistics between parentheses, *** significance at 1% level, ** significance at 5% level,

* significance at 10% level.

5.4.5 Marginal effects of *TR* and *FG*

Overall marginal effects of *TR* and *FG* are calculated for the above 4 models and presented in Table 5.13. Critical values of income per capita below which the marginal effects are negative are also reported.

Table 5.13: Overall marginal effects of fiscal imbalance

	TR				*FG*			
	SFA 1	SFA 2	SFA 3	IV	SFA 1	SFA 2	SFA 3	IV
Mean	0.028	0.003	0.016	0.045	0.008	-0.002	0.017	0.012
Minimum	-0.073	-0.089	-0.074	-0.049	-0.060	-0.063	-0.042	-0.043
Lower quartile	-0.004	-0.026	-0.013	0.015	-0.014	-0.022	-0.002	-0.006
Median	0.026	0.001	0.014	0.043	0.006	-0.004	0.016	0.011
Upper quartile	0.051	0.023	0.035	0.065	0.022	0.011	0.030	0.024
Maximum	0.137	0.101	0.112	0.145	0.079	0.063	0.080	0.071
S.D.	0.042	0.038	0.049	0.039	0.028	0.026	0.032	0.023
Critical value of income per capita	1726.152	2450.316	2008.774	1304.812	2190.907	2719.403	1699.318	1891.735
% of observations with negative marginal effects	27.0%	47.3%	37.8%	12.2%	43.2%	57.4%	27.0%	33.8%
Observation number	148	148	148	148	148	148	148	148
Dropped province	Qinghai	Qinghai	Qinghai	Qinghai	Qinghai	Qinghai	Qinghai	Qinghai

Note: SFA 1 stands for SFA model with *Dev*. SFA 2 stands for SFA model with *LDev*. SFA 3 stands for SFA model with control function. Critical value of income per capita is in 2005 USD.

Among models with *TR*, the IV estimator gives the lowest critical value of income per capita at 1305 USD (with 12.2% of all observations having negative marginal effects), while SFA with *LDev* gives the highest critical value of income per capita at 2450 USD (with 47.3% of all observations having negative marginal effects). Among models with *FG*, SFA with control function gives the lowest critical value of income per capita at 1699 USD (with 27% of all observations having negative marginal effects), while SFA with *LDev* gives the highest critical value of income per capita at 2719 USD (with 57.4% of all observations having negative marginal effects).

5.5 Conditional environmental efficiency

In this subsection, *CEE* scores are calculated using results of the second-stage SFA. Although different SFA specifications give consistent results regarding nonlinear effects of *TR* and *FG*, the one with *TR* and predicted residuals of control function has the highest log likelihood value. According to the Akaike information criterion (AIC), this model is preferred because it has the minimum AIC value. Thus, the adjusted environmental efficiency scores are calculated based on SFA with *TR* and control function.

Table 5.14: Summary of overall and regional CEE scores

	Overall	North	Northeast	East	Center	South	Southwest	Northwest
Mean	69.3%	62.5%	74.2%	84.5%	69.8%	75.0%	63.3%	48.9%
Minimum	10.2%	31.7%	53.5%	57.1%	62.9%	58.8%	29.9%	9.9%
Lower quartile	57.4%	41.1%	54.3%	75.9%	63.5%	59.5%	47.2%	23.9%
Median	71.8%	68.6%	71.4%	89.2%	71.0%	71.0%	66.6%	39.1%
Upper quartile	89.6%	70.7%	97.0%	99.5%	74.8%	94.7%	79.7%	73.1%
Maximum	99.6%	99.6%	97.1%	99.5%	75.2%	94.7%	89.7%	87.8%
S.D.	0.233	0.243	0.183	0.140	0.050	0.152	0.218	0.301
Nb. of ob.	148	25	15	35	15	15	20	23
Dropped province	N.a.	N.a.	N.a.	N.a.	N.a.	N.a.	N.a.	Qinghai

Summary of provincial overall *CEE* scores by region is presented in Table 5.14. It is remarkable that Chinese provinces have on average relatively higher conditional *EE* scores once external variables are controlled for. *CEE* scores vary from 10.9% to 99.6% with an overall mean of 68.8%. Among the seven regions, East China has the highest mean scores (84.5%), followed by South China (75.0%) and Northeast China (74.2%). Northwest China has the lowest mean scores (48.9%), far behind the others. Summary of *CEE* by year is presented in Table 5.15. It seems that *CEE* scores are relatively stable over this period. The three provinces with the highest mean *CEE* scores are Beijing (99.6%), Fujian (99.5%) and Jiangxi (99.5%). The three provinces with the lowest mean *CEE* scores are Ningxia (10.9%), Qinghai (24.3%) and Guizhou (30.5%). The concordance between *EE* ranking and *CEE* ranking is positive and significant: The Spearman rank correlation coefficient between the two measures is 0.770. The null hypothesis that the two rankings are independent can thus be strongly rejected. The ranking list of mean *EE* and *CEE* scores can be found in Appendix 5.9.

Table 5.15: Summary of *CEE* by year

	2005	2006	2007	2008	2009
Mean	69.4%	69.6%	68.2%	68.4%	68.6%
Minimum	9.9%	10.4%	10.9%	11.4%	11.8%
Lower quartile	58.8%	59.1%	57.5%	57.8%	58.0%
Median	70.7%	70.9%	71.0%	71.2%	71.3%
Upper quartile	88.5%	88.6%	88.6%	88.7%	88.8%
Maximum	99.6%	99.6%	99.6%	99.6%	99.6%
S.D.	0.229	0.228	0.238	0.237	0.236
Observation number	29	29	30	30	30
Dropped province	Qinghai	Qinghai	N.a.	N.a.	N.a.

5.6 Concluding remarks

Decentralization has been promoted by major international institutions. Proponent arguments defending the merits of decentralization are abundant. However, many studies show that decentralization may be inefficient for environmental protection. China's one-sided fiscal decentralization has shown an example. After 1994, public expenditures are largely decentralized while fiscal revenues are recentralized. Sub-national governments have huge fiscal imbalance and depend basically on transfers to fulfill their expenditure responsibilities. It seems that this critical situation may have negative effects on environmental protection. Localities, especially the poor ones, are likely to under-provide environmental protection service either due to incapacity or unwillingness.

In this chapter, I study empirically the environmental effect of this one-sided decentralization. Precisely, I examine whether fiscal imbalance caused by this decentralization improves or reduces environmental efficiency of Chinese provinces.

Following the two-stage *EE* model developed by Reinhard *et al.* (2000), I first calculate with SFA the *EE* scores of Chinese provinces' gross regional product over the period of 2005-2010. After that, using four alternative models, *EE* scores are regressed against two fiscal imbalance indicators, *VI* and *FG*, in order to test the linear and nonlinear effects of the latter. Finally, adjusted *EE* scores are calculated conditional on fiscal imbalance and other underground variables.

The empirical results are robust and interesting to interpret. During the period of study, fiscal imbalance has nonlinear effects on *EE* of Chinese provinces. Moreover, these effects seem to be conditional on economic development level, i.e., fiscal imbalance is likely to be more detrimental in less affluent provinces. This finding suggests the vulnerability of poor localities in face of severe fiscal pressures. In at least 12% of the cases, larger fiscal imbalance reduces *EE*. Fiscal imbalance can be more detrimental to poorer provinces for several reasons. First, poor provinces may be fiscally incapable to ensure environmental service due to the lack of resources; secondly, with limited resources, poorer provinces would sacrifice environmental service for more "productive" ones; and thirdly, poorer provinces may use sub-optimal environmental stringency as a tool to generate more taxable resources.

Once external factors are controlled for, Chinese provinces have on average a conditional *EE* score of 69.3%, considerably higher than 57.3% before the adjustment. This shift suggests that the overall external context in China contributes to environmental inefficiency. If all provinces had the same external context as that of the most advantageous one, mean *EE* would increase from 57.3% to 69.3%.

Results obtained in this chapter call for attention to the potential negative environmental effects of the one-sided fiscal decentralization in poor Chinese provinces. Too many responsibilities without adequate revenues can lead to inefficient resource allocation; severe fiscal pressures may encourage poor localities to engage in short-term behaviors, e.g. developing economy at the cost of environment. Moreover, since the effects are nonlinear, it seems that this fiscal decentralization has regressive environmental effects in that it contributes to the disparity across regions in terms of sustainable development. Although the choice between more revenue autonomy and less expenditure responsibilities is still a political debate in China, it is a certainty that the balance between expenditure responsibilities and revenue assignments need to be redressed for a more sustainable and equitable development across Chinese regions.

Appendix 5.1: Name and description of variables

Variable	Description
Y	Gross regional product (10000 USD at 2005 price)
K	Provincial capital stock (10000 RMB at 1952 price)
L	Total provincial employment at the end of year (10000 persons)
T	Time trend
E	Total energy consumption (ton of Standard Coal Equivalent)
TR	Share of central transfers in provincial expenditures
FG	Fiscal gap
Dev	Income per capita (2005 USD)
Open	(Exportation + Importation)/ Gross regional product
FDI	Foreign direct investments/ Gross regional product
Edu	Illiterate rate
Unemployment	Unemployment rate
Urban	Non-agricultural population/total population
State	Employment of state-owned sector/total employment
Density	Population /km^2
Growth	Growth rate of regional gross product
Coast	1 if coast province, 0 otherwise
Dum2006	1 if the year of 2006, 0 otherwise
Dum2007	1 if the year of 2007, 0 otherwise
Dum2008	1 if the year of 2008, 0 otherwise
Dum2009	1 if the year of 2009, 0 otherwise

Appendix 5.2: Summary statistics of variables

Variable	Obs.	Mean	S.D.	Min	Max
Y	180	14300000	12900000	663023	69500000
K	180	54300000	49100000	3714443	263000000
L	180	2423.416	1602.439	267.619	6041.557
T	180	3.500	1.713	1	6
E	179	138000000	94900000	8221845	497000000
TR	148	0.509	0.183	0.141	0.857
FG	148	0.478	0.182	0.078	0.818
Dev	148	3102.874	2125.191	616.500	11862.610
Open	148	0.359	0.410	0.045	1.668
FDI	148	0.026	0.020	0.001	0.082
Edu	148	0.088	0.046	0.028	0.223
Unemployment	148	0.038	0.006	0.014	0.056
Urban	148	0.367	0.164	0.158	0.880
State	148	0.111	0.048	0.053	0.245
Density	148	411.474	534.697	7.667	3029.969
Growth	148	0.173	0.056	0.006	0.323
Coast	148	0.372	0.485	0	1
Dum2006	148	0.196	0.398	0	1
Dum2007	148	0.203	0.403	0	1
Dum2008	148	0.203	0.403	0	1
Dum2009	148	0.203	0.403	0	1

Appendix 5.3: Linear effect of *TR* and *FG* with truncated normal distribution

	With *TR*		With *FG*	
Constant	1.322*	(1.723)	1.386*	(1.762)
TR	0.004	(0.210)		
FG			0.019	(1.141)
Dev^3	-0.004**	(-2.205)	-0.004**	(-2.137)
Dev^2	0.083**	(2.136)	0.082**	(2.093)
Dev	-0.569*	(-1.883)	-0.568*	(-1.866)
Open	0.021**	(2.448)	0.019**	(2.121)
Fdi	-0.195**	(-2.342)	-0.172**	(-1.993)
Edu	-0.111*	(-1.885)	-0.112**	(-1.918)
Unemployment	-0.164	(-0.609)	-0.172	(-0.642)
Urban	-0.041	(-0.719)	-0.053	(-0.863)
State	-0.097	(-1.463)	-0.101	(-1.521)
Density	0.118***	(3.689)	0.114***	(4.045)
Coast	0.124***	(3.112)	0.117***	(3.075)
D2006	-0.010***	(-4.490)	-0.010***	(-4.479)
D2007	-0.018***	(-4.383)	-0.018***	(-4.346)
D2008	-0.024***	(-3.480)	-0.024***	(-3.506)
D2009	-0.037***	(-4.348)	-0.038***	(-4.460)
σ^2	0.049	(1.545)	0.045*	(1.911)
γ	1.000***	(3243.698)	1.000***	(3906.683)
μ	0.153	(0.982)	0.183	(1.655)
η	0.006**	(2.635)	0.007***	(3.046)
Log likelihood function	456.362		456.970	

Note: *t-student* statistics between parentheses, *** significance at 1% level, ** significance at 5% level, * significance at 10% level.

Appendix 5.4: Nonlinear effect of *TR* and *FG* with truncated normal distribution

	With *VI*		With *FG*	
constant	0.852	(1.170)	1.946***	(2.643)
TR	-0.525***	(-4.230)		
$TR*Dev$	0.070***	(4.334)		
FG			-0.360***	(-3.546)
$FG*Dev$			0.047***	(3.789)
Dev^3	-0.001	(-0.845)	-0.004***	(-2.975)
Dev^2	0.036	(0.951)	0.103***	(2.948)
Dev	-0.301	(-1.042)	-0.778***	(-2.806)
Open	0.011	(1.323)	0.004	(0.437)
Fdi	-0.154*	(-1.918)	-0.171**	(-2.139)
Edu	-0.077	(-1.399)	-0.115**	(-2.108)
Unemployment	-0.124	(-0.499)	-0.093	(-0.371)
Urban	0.002	(0.033)	-0.031	(-0.847)
State	-0.088	(-1.417)	-0.098	(-1.608)
Density	0.140***	(7.380)	0.141***	(18.083)
Coast	0.141***	(11.629)	0.143***	(11.975)
D2006	-0.007***	(-3.241)	-0.008***	(-3.659)
D2007	-0.012***	(-2.936)	-0.013***	(-3.424)
D2008	-0.015**	(-2.366)	-0.017***	(-2.607)
D2009	-0.029***	(-3.653)	-0.031***	(-3.890)
σ^2	0.062	(1.611)	0.065*	(1.726)
γ	1.000***	(4983.027)	1.000***	(5332.281)
μ	0.096	(0.646)	0.081	(0.612)
η	0.005***	(3.208)	0.005***	(3.511)
Log likelihood function	464.771		463.607	

Note: *t-student* statistics between parentheses, *** significance at 1% level, ** significance at 5% level, * significance at 10% level.

Appendix 5.5: 1st- stage and tests of IV with *TR*

	Dev^3		Dev^2		*Dev*		$TR*Dev$	
TR	-185.999	(-0.950)	-14.221	(-0.890)	-0.780	(-0.790)	-0.092	(-0.140)
Density	-117.500	(-1.450)	-11.643*	(-1.780)	-0.845**	(-2.080)	-0.611**	(-2.380)
Open	-7.484	(-0.550)	-0.558	(-0.510)	-0.029	(-0.430)	-0.013	(-0.280)
Fdi	48.793	(0.350)	6.598	(0.580)	0.573	(0.800)	0.517	(1.060)
Edu	-44.157	(-0.550)	-5.590	(-0.880)	-0.479	(-1.230)	-0.413*	(-1.800)
Unemployment	-126.100	(-0.340)	-11.136	(-0.350)	-0.726	(-0.350)	-0.583	(-0.460)
Urban	200.252**	(2.180)	14.971**	(2.090)	0.825*	(1.920)	0.137	(0.500)
State	9.809	(0.100)	-0.030	(-0.000)	-0.055	(-0.110)	-0.137	(-0.380)
Dum2006	15.438***	(2.940)	1.293***	(3.420)	0.082***	(3.940)	0.031***	(2.690)
Dum2007	43.623***	(4.900)	3.706***	(5.840)	0.238***	(6.960)	0.103***	(5.580)
Dum2008	76.291***	(5.800)	6.489***	(6.930)	0.416***	(8.230)	0.189***	(6.910)
Dum2009	78.034***	(3.990)	6.707***	(4.800)	0.436***	(5.740)	0.178***	(4.400)
Lgrowth	60.013**	(2.540)	5.086**	(2.550)	0.326**	(2.530)	0.151	(1.630)
LDev	-109.483	(-0.220)	-0.151	(-0.000)	1.460	(0.600)	1.850	(1.210)
$LDev^2$	4.506	(0.070)	0.073	(0.010)	-0.130	(-0.400)	-0.286	(-1.400)
$LDev^3$	0.667	(0.220)	0.031	(0.130)	0.005	(0.360)	0.013	(1.410)
$TR*LDev$	12.334	(0.490)	1.032	(0.500)	0.061	(0.470)	1.042***	(11.790)
R^2	0.992		0.992		0.993		0.995	
Test of excluded instruments	$Prob > F$ = 0.000		$Prob > F$ = 0.000		$Prob > F$ = 0.000		$Prob > F$ = 0.000	
Kleibergen-Paap rk LM statistic	$Prob > chi2$=0.002							
Anderson-Rubin Wald test	$Prob > chi2$= 0.000							
Hansen J statistic	$Prob > chi2$= 0.773							
IV redundancy tests	$LDev^3$: $Prob > chi2$= 0.003 $LDev^2$: $Prob > chi2$= 0.004 $LDev$: $Prob > chi2$= 0.005 $Lgrowth$: $Prob > chi2$= 0.027 $VI*LDev$: $Prob > chi2$= 0.000							
Nb. of obs.	148		148		148		148	

Note: estimates are calculated with heteroskedasticity robust standard errors.

Appendix 5.6: 1st- stage and tests of IV with *FG*

	Dev^3		Dev^2		Dev		$FG*Dev$	
FG	-332.731*	(-1.750)	-21.451	(-1.490)	-0.948	(-1.130)	0.344	(0.670)
Density	-14.742	(-0.180)	-4.471	(-0.690)	-0.483	(-1.210)	-0.627***	(-2.670)
Open	-19.459	(-1.380)	-1.335	(-1.200)	-0.065	(-0.950)	0.002	(0.050)
Fdi	46.404	(0.310)	6.795	(0.560)	0.611	(0.810)	0.673	(1.390)
Edu	-41.232	(-0.510)	-5.491	(-0.840)	-0.479	(-1.200)	-0.497**	(-2.230)
Unemployment	-382.268	(-1.010)	-29.321	(-0.920)	-1.668	(-0.810)	-0.399	(-0.360)
Urban	258.258**	(2.310)	18.374**	(2.130)	0.952**	(1.880)	0.072	(0.240)
State	33.631	(0.320)	1.558	(0.180)	0.020	(0.040)	-0.155	(-0.480)
Dum2006	13.300***	(2.780)	1.132***	(3.190)	0.073***	(3.610)	0.022**	(2.000)
Dum2007	37.975***	(4.870)	3.291***	(5.740)	0.215***	(6.690)	0.084***	(5.000)
Dum2008	69.203***	(6.010)	5.950***	(7.000)	0.386***	(8.040)	0.157***	(6.150)
Dum2009	64.691***	(3.850)	5.714***	(4.540)	0.381***	(5.290)	0.134***	(3.480)
Lgrowth	59.968**	(2.440)	5.111**	(2.460)	0.329**	(2.460)	0.166*	(1.800)
LDev	-468.304	(-0.910)	-25.505	(-0.620)	0.174	(0.070)	1.996	(1.410)
$LDev^2$	49.119	(0.730)	3.264	(0.610)	0.034	(0.100)	-0.300	(-1.620)
$LDev^3$	-1.195	(-0.400)	-0.102	(-0.430)	-0.002	(-0.110)	0.014*	(1.670)
$FG*LDev$	42.385*	(1.720)	2.783	(1.510)	0.127	(1.190)	0.992***	(15.670)
R^2	0.991		0.992		0.993		0.998	
Test of excluded instruments	$Prob > F$ = 0.000		$Prob > F$ = 0.000		$Prob > F$ = 0.000		$Prob > F$ = 0.000	
Kleibergen-Paap rk LM statistic	$Prob > chi2$=0.002							
Anderson-Rubin Wald test	$Prob > chi2$= 0.000							
Hansen J statistic	$Prob > chi2$= 0.629							
IV redundancy tests	$LDev^3$: $Prob > chi2$= 0.002 $LDev^2$: $Prob > chi2$= 0.003 $LDev$: $Prob > chi2$= 0.004 $Lgrowth$: $Prob > chi2$= 0.065 $FG*LDev$: $Prob > chi2$= 0.000							
Nb. of obs.	*148*		*148*		*148*		*148*	

Note: estimates are calculated with heteroskedasticity robust standard errors.

Appendix 5.7: Specification tests with *LDev*

Indicator	Specification	Null hypothesis	Tested against	Log likelihood	Likelihood ratio	$Prob > \chi^2$	Decision
TR	1. Truncated-normal stochastic			460.231			
TR	2. Absence of U_{it}	$\gamma = 0$	1	95.233	729.996	0.000	rejected
TR	3. Half-normal	$\mu = 0$	1	460.107	0.248	0.619	accepted
TR	4. Time-invariant	$\mu = 0, \eta = 0$	3	455.262	9.689	0.002	rejected
FG	5. Truncated-normal stochastic			459.407			
FG	6. Absence of U_{it}	$\gamma = 0$	5	92.619	733.576	0.000	rejected
FG	7. Half-normal	$\mu = 0$	5	459.316	0.181	0.670	accepted
FG	8. Time-invariant	$\mu = 0, \eta = 0$	7	453.935	10.762	0.001	rejected

Appendix 5.8: Specification tests with control function method

Indicator	Specification	Null hypothesis	Tested against	Log likelihood	Likelihood ratio	$Prob > \chi^2$	Decision
TR	1. Truncated-normal stochastic			468.305			
TR	2. Absence of U_{it}	$\gamma = 0$	1	96.161	744.289	0.000	rejected
TR	3. Half-normal	$\mu = 0$	1	468.405	-0.199	1.000	accepted
TR	4. Time-invariant	$\mu = 0, \eta = 0$	3	462.948	10.914	0.001	rejected
TR	5. Without predicted residuals	Coefficients of predicted residuals are jointly = 0	3	464.675	7.460	0.113	accepted
FG	6. Truncated-normal stochastic			467.858			
FG	7. Absence of U_{it}	$\gamma = 0$	5	94.082	747.551	0.000	rejected
FG	8. Half-normal	$\mu = 0$	5	467.771	0.174	0.677	accepted
FG	9. Time-invariant	$\mu = 0, \eta = 0$	7	461.924	11.695	0.001	rejected
	10. Without predicted residuals	Coefficients of predicted residuals are jointly = 0	7	463.529	8.484	0.075	accepted

Appendix 5.9: Ranking list of mean *EE* and *CEE* scores

Province	*CEE* ranking	*EE* ranking	mean *CEE* score	mean *EE* score	Region
Beijing	1	2	0.996	0.974	North
Jiangxi	2	8	0.995	0.760	East
Fujian	3	4	0.995	0.942	East
Heilongjiang	4	11	0.970	0.600	Northeast
Guangdong	5	1	0.947	0.988	South
Anhui	6	9	0.902	0.748	East
Zhejiang	7	5	0.892	0.914	East
Yunnan	8	14	0.886	0.571	Southwest
Xinjiang	9	24	0.877	0.320	Northwest
Jiangsu	10	6	0.796	0.857	East
Shanghai	11	3	0.758	0.970	East
Hunan	12	13	0.750	0.593	Center
Shaanxi	13	18	0.728	0.524	Northwest
Jilin	14	21	0.714	0.503	Northeast
Guangxi	15	10	0.710	0.619	South
Hubei	16	15	0.710	0.564	Center
Inner Mongolia	17	25	0.705	0.313	North
Sichuan	18	22	0.693	0.489	Southwest
Tianjin	19	7	0.686	0.770	North
Chongqing	20	19	0.638	0.516	Southwest
Henan	21	16	0.633	0.557	Center
Hainan	22	17	0.593	0.532	South
Shandong	23	12	0.575	0.599	East
Liaoning	24	20	0.540	0.509	Northeast
Hebei	25	23	0.414	0.401	North
Gansu	26	28	0.388	0.210	Northwest
Shanxi	27	26	0.325	0.244	North
Guizhou	28	27	0.305	0.217	Southwest
Qinghai	29	29	0.243	0.071	Northwest
Ningxia	30	30	0.109	0.068	Northwest

General Conclusion

Main results

The large body of environmental federalism literature is composed of lasting and inconclusive debate. While some highlight numerous merits of decentralization in resource allocation and local public good provision, others are more skeptical and argue that it may also lead to inefficient environmental policy making or enforcement. In a country as broad and diverse as China, the merits of decentralization seem particularly attractive and promising. Effectively, since environmental concerns, preferences, and problems vary from place to place within this country, local knowledge and expertise are indispensable to develop proper solutions for environmental problems with local and regional nature. However, despite the *de facto* environmental federalism adopted in China, dramatic environmental crises and policy failures widespread since its economic reforms. In particular, more recently, this country has seen arise many problems predicted by the opponents of decentralization. It appears that, contrary to the fiscal decentralization which has substantially promoted resource mobilization and economic growth, the decentralization of environmental policy implementation hasn't worked so well in enforcing environmental regulation at sub-national level (General Introduction).

With the purpose of providing a better and detailed understanding of the *de facto* environmental federalism in China, this thesis follows the different critics in the literature and test empirically for each of them in the Chinese-specific context. The main findings of the present dissertation can be summarized as follows.

This dissertation begins with a comprehensive discussion of the *de facto* federalism (both environmental and fiscal) in China (Chapter 1). This discussion makes it obvious that problems associated with decentralization have been to a great extent responsible for the widespread environmental policy failures at sub-national level in China. Given the structural conflicts between economic growth and environment and the national priority on economic growth, the *de facto* environmental federalism and the one-sided fiscal decentralization have jointly provided Chinese sub-national governments with effective autonomy as well as strong economic incentives to exercise weak enforcement of environmental regulations. In such an institutional context, it is not surprising that autonomy in environmental policy enforcement at sub-national level has been used to facilitate economic growth rather than (or even in sacrificing) environmental protection.

Following the three main critics of environmental federalism in the literature, this thesis goes on to conduct a series of empirical studies in the Chinese-specific context, in order to shed light on the efficiency of the *de facto* environmental federalism in China (Chapters 2, 3 and 4).

First of all, the problems related to environmental externality is examined in Chapter 2. If the border-effect related to pollution free-riding behaviors has been tested for in the U.S. or cross-country context, no existing literature has studied this effect in China to the knowledge of the author. Using a unique dataset of polluting firms and county-level geographical information of Hebei province, this chapter studies the location choice of recently created polluting firms in Hebei and finds significant evidence of the border-effect. In effect, during the period of 2002-2008, counties share a (large part of) common border with another province attract significantly more polluting firms than interior counties; the closer a county is to the border, the higher is its probability to attract polluting firms. As a result, it seems that inter-regional pollution free-riding behaviors do exist in China. Consequently, border counties suffer disproportionately from pollution because of externality. Moreover, this problem deserves particular attention because the border-effect has strengthened over time.

After that, in Chapter 3, I continue to test for the second critic to environmental federalism- inter-jurisdictional strategic interaction in environmental policymaking. Using spatial econometric methods and different identification strategies, this chapter tests for the two theoretical assumptions behind the potential strategic interaction: the capital-competition model and the pollution-spillovers model. Estimation results suggest that Chinese provinces do engage in strategic interaction, i.e., they take into account decisions of other provinces into their own decision, when they fix their environmental stringency and SO2 emission level. In particular, competition for capital would drive them to interact positively with each other in stringency setting, while pollution spillover considerations would drive them to interact negatively with each other in SO2 emission. Moreover, it seems that provincial fiscal imbalance due to the one-sided fiscal decentralization significantly strengthens the capital-competition driven interaction. Nevertheless, the asymmetric interaction pattern predicted by “the race to the bottom” theory hasn’t been found.

Chapter 4 furthermore tests for the third critic proposed by environmental federalism opponents, i.e. “public choice” related rationales. From a political economy point of view, this chapter examines how political incentives affect provincial environmental performance before and after 2006. For this purpose, the ex-ante average growth rate score and the age 65 are used respectively as proxies of provincial leaders’ political competitiveness and term limit. In revisiting the EKC hypothesis, empirical results of this chapter indicate that, *ceteris paribus*, the less competitive the leader is on the political market, the more he would compromise environment. Moreover, this political-competitiveness effect is significantly conditional on term limit. A leader of 65 or older would not conduct such environment-sacrificing behaviors even if he has less competitive economic performance score, due to his *quasi* null political career prospect. Finally, this effect has been mitigated by the new “pro-environmental” changes since 2006.

At last, after examining the three critic hypotheses related to environmental federalism, particular attention is paid in Chapter 5 to the role of the one-sided fiscal decentralization side by side with the *de facto* environmental federalism. To this end, the environmental efficiency of provincial gross production and its determinants are estimated with a two-stage environmental efficiency model. As predicted, estimation results suggest that fiscal imbalance does affect provincial environmental performance in China. Precisely, fiscal imbalance has a nonlinear effect on *EE* scores, which is conditional on the economic development level of the province. The less the province is affluent, the more its fiscal imbalance would be detrimental to its *EE*, *vice versa*. In the most poor cases (at least 12%), larger fiscal imbalance reduces *EE*. This finding confirms the vulnerability of poor localities in terms of sustainable development when they face severe fiscal pressures. It seems that the one-sided fiscal decentralization in China does have perverse repercussion on environment in poor provinces. In addition, the overall external context also contributes to environmental inefficiency in China.

Political implications

The series of empirical studies in this thesis sheds light on the efficiency of the current *de facto* environmental federalism in China. Results obtained in this thesis provide supportive evidence of the opponent arguments on decentralization. Apparently, the *de facto* environmental federalism has been a "grabbing hand" rather than a "helping hand" for environmental governance in China.

However, although the *de facto* environmental federalism has shown numerous problems, it doesn't mean that a centralized environmental policy implementation is preferred. In practice, many environmental problems are local and regional in nature, which requires localized knowledge and treatments. Inevitably, much of localized information is beyond the reach of even the most observant central government. For example, the most effective and equitable strategy for controlling air pollution will vary from city to city depending on the local mix of pollution sources, dominant weather conditions and population's preference. Some U.S. scholars argue that environmental policy should be informed by the idea of subsidiarity, where each environmental problem is dealt with by the level of government best positioned to address that particular concern (Esty, 1996). As Esty explains, "The challenge is to find the best fit possible between environmental problems and regulatory responses—not to pick a single level of government for all problems."

As a result, it seems that it's not environmental federalism itself which should be called into question; the questions that Chinese policymakers should really care about are (1) how to better organize environmental federalism given the country-specific characteristics and (2) how to form suitable incentives for local officials in order that environmental federalism become a "helping hand" in the country's environmental management.

a. A new environmental federalism

It is crucial to develop "a new environmental federalism" in China, i.e. a better reorganization of environmental federalism dependent upon the Chinese-specific characteristics.

First, one of the fundamental problems in the Chinese environmental governance is related to the multi-level governance. In China, local EPBs are subordinated to local governments which have the authority to interfere with local environmental affairs. To overcome this problem, Xue *et al.*(2006) propose a realignment of local environmental management to create a direct vertical line of environmental authority. Although China hasn't yet seen this direct vertical line emerge, six regional MEP offices do have the responsibility to reinforce the vertical control of the MEP. Nevertheless, the effectiveness of these regional offices' work needs further investigation.

Secondly, targeted solutions should be formulated to coordinate inter-regional environmental conflicts, such as the cross-boundary pollution problems. In effect, numerous candidate mechanisms can help to address inter-regional environmental conflicts (Adler, 1998), e.g. inter-regional compacts, regional authorities, pollution trading and inter-regional ecological compensation. It is notable that the creation of the MEP regional offices has also the objective to coordinate inter-regional interests. In addition, although emission trading and ecological compensation practices can be traced back to as early as 1980's in China (Sun and Zhou, 2008), both systems are still under construction. Several pilot emission trading and inter-regional ecological compensation projects have been launched since the 11th FEYP (Zhang *et al.*, 2007). In summary, targeted solutions are under formulation but not yet really in place.

Inevitably, a new environmental federalism will unleash greater experimentation and innovation. Fortunately, the spirit of experimentation is something that the

Chinese government has kept in mind since the economic reforms and that has proven to work well in promoting growth. Hope that this spirit will also benefit the environmental protection.

b. Form a grabbing hand to a helping hand

The "new environmental federalism" will not work efficiently unless another problem is resolved. As argued by Jin *et al.* (2005), decentralization can be either a "help hand" or a "grabbing hand" for tax mobilization; environmental federalism can also be either helpful or detrimental for environmental protection, all depending on incentives faced by local officials. This thesis shows that, until very recently, the *de facto* environmental federalism has rather been a "grabbing hand". It is not the federalism which has created the pollution in China, but it has definitely aggravated the situation.

In fact, since the political priority has been given to economic growth, the federalism has created strongly skewed economic and political incentives. Chinese local officials who face these incentives have naturally promoted economic growth in sacrificing environment.

In order to transform the "grabbing hand" to a "helping hand", it is fundamental to rebalance the formerly skewed incentives. If and only if local governments become stakeholders of and accountable for their environment performance that they will effectively involve in meeting environmental goals (Xue *et al.*, 2006). The new government responsibility system is one step towards this direction. Another meaningful effort is seen in the 2008 amendments of the water pollution law, which provide more robust responsibilities for environmental outcomes under the bureaucratic evaluation system. From then on, local official are accountable for their environmental outcomes because the fulfillment of water environmental protection targets constitutes a part of their evaluation criteria (Lan *et al.*, 2011). With these "pro-environment" changes in the bureaucratic system since 2006, the Chinese government has maintained the decentralization and allowed local flexibility (Golding, 2011). However, as argued by Golding, the effects of these measures will be conditional on citizen involvement, data transparency and public accountability.

Fortunately, growing public participation has been observed since several years, which has furthermore helped shifting political incentive towards environmental protection. Actually, China has seen an increasing sensibility of its citizens on environmental issues: Environment NGOs have expanded during one decade.[103] More and more pollution victims go complain.[104] In some extreme cases, pollution has conducted to acute conflicts even violence, which threaten the local security and governance stability.[105] Pollution problems have been largely unmasked and discussed in the media especially on internet. All of these exercise a greater pressure on local governments than any other moment in history. In some cases, citizen voice has indeed reversed political decisions.[106] Some officials did lose their posts because of public pressure after environmental crisis.[107] In summary, growing public participation (either through media or through real protests) contributes to increase Chinese local governments' accountability, which is decisive and indispensible for the change from the "grabbing hand" to a "helping hand", and for better environmental governance in this country.

In the end, one must recognize that although environment goals have been included in national development priority by the CCP and the Chinese central

[103] The first environment NGO in China was created in 1994. At the end of 2008, there were more than 3500 environment NGOs in China, according to All-China Environment Federation. http://news.xinhuanet.com/environment/2008-10/30/content_10282938.htm.

[104] In 2009, the Ministry of Environmental Protection of China received 29500 cases of complaints about pollutions, among which 13100 were on internet (China Environment Yearbook, 2010).

[105] Two recent cases took place in Lianhua county, Jiangxi province in August 2011 and in Haining county, Zhejiang province in September 2011, where peasants protested local factories' pollution and had conflicts with the police. http://www.chinese.rfi.fr/中国.

[106] For example, due to public pressure in December 2007, the government of Xiamen, Fujian province, reportedly halted construction on a Taiwanese-invested paraxylene (PX) petrochemical plant and moved it out of the city. This event is generally considered as a victory for public participation in China. http://www.chinadialogue.net/article/show/single/en/1626.

[107] Xie Zhenghua, former director of SEPA, was relieved of his office after the pollution event of the Songhua River in November 2005. http://www.china.org.cn/english/2005/Dec/150724.htm. In the last two years, numerous local officials were dismissed in Inner Mongolia and Hunan because of pollution accidents. http://www.360doc.com/content/09/0806/22/204175_4717024.shtml; http://news.xinhuanet.com/local/2010-03/23/content_13226362.htm.

government, it stays subject to trade off with other social goals e.g. universal illness assurance and equitable education, etc. As long as the development resource is limited, trade-off is inevitable. As a result, research on the relationship between decentralization and more efficient resource allocation has important political implication. This is especially true in a country like China, where the contrast between development need and resource constraint is so huge.

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